Sokoine University of Agriculture

PhD Thesis

Effectiveness of Community Based Health Education Intervention on the Control of Human *Taenia solium* Taeniasis / Cysticercosis in Kongwa and Songwe Districts, Tanzania

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May, 2024

Effectiveness of Community Based Health Education Intervention on the Control of Human *Taenia solium* Taeniasis / Cysticercosis in Kongwa and Songwe Districts, Tanzania

Thesis submitted to Sokoine University of Agriculture in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

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A Thesis Submitted In Fulfilment of the Requirements for the Degree of Doctor of Philosophy of Sokoine University of Agriculture
Morogoro, Tanzania

May, 2024

EXTENDED ABSTRACT

Taenia solium taeniasis/cysticercosis are neglected tropical diseases and infections transmitted between humans and pigs, causing economic and public health impact in affected communities. The diseases and infections have received great attention in recent years and now are included in the global agenda of neglected tropical diseases. However, little efforts are in place for the control in sub-Saharan Africa (SSH), a highly endemic region. Tanzania is among the SSH countries where the diseases and infections are endemic especially in districts that keep high number of pigs. Control measures recommended to combat these diseases and infections include improvements in hygiene, sanitation and pig management, mass taeniacidal chemotherapy and health education. Health education is the cornerstone of health promotion and has been defined as the lifelong process by which individuals acquire knowledge, attitudes and behaviour that promote health and foster wise decisions for solving personal, family and community health problems. However, there are limited studies to evaluate community-based health education interventions in endemic areas of the country. The current study on community health education on *T. solium* taeniasis / cysticercosis was conducted between July 2019 and December 2021 in Kongwa and Songwe Districts, Tanzania. The general aim of this study was to determine the effectiveness of a developed community based health education intervention to increase community knowledge, improve preventive measures and reduce incidences of human *T. solium* taeniasis/cysticercosis in the study area. To achieve this, all villages from Kongwa and Songwe Districts were assessed for their eligibility to participate in the study targeting on selecting 42 villages and estimated sample size of 872 people. Randomized controlled trial design was used, where villages were randomly assigned into two groups, 21villages as control group and other 21 villages as intervention group. The study was conducted in three key phases, including the baseline phase whereby the baseline data were assessed, health education intervention phase whereby the education intervention was performed and the post intervention phase whereby the education intervention was assessed

for its effectiveness. The study recruited the same participants in all the three phases.

At baseline phase which was conducted between June and September in 2019, a questionnaire survey was conducted in both village groups to assess community knowledge and practices associated with transmission of human *T. solium* infections. In each village, 20 to 25 households were randomly selected to participate, and in each household, one person was randomly selected to represent the household. The respondent was consented, interviewed and sampled 5 mls of blood from the cephalic or median cubital vein (median basilic vein) by a medical laboratory technician for *T. solium* cysticercosis detection. The sera were examined for presence of excretory secretory circulating antigens of the metacestode of *T. solium* using enzyme-linked immunosorbent assay (Ag-ELISA) and Western blot IgG kit (WB-IgG), which is an immunological method for detection of exposure to *T. solium*. During the second phase which was conducted between July and August 2020, community based health education intervention trial was implemented using the health education package. The health education was implemented by first training livestock/agricultural extension officers, school teachers, health workers and village leaders to serve as local trainers for knowledge sustainability purpose. Subsequently, the local trainers and the researcher trained a total of 440 participants from 21 intervention villages and 432 participants from the 21 control villages were not trained. The third phase was conducted between September and December in 2021 a year after intervention, whereby the questionnaire survey and blood sampling were repeated in selected study households of the 42 selected villages and was planned to use the same respondents of phase one. The purpose was to assess the same factors that were assessed during the baseline phase. However, only 320 respondents were available in the control villages and 342 in the intervention villages. A total of 210 participants were lost during the follow up period that constituted 98 participants from the intervention villages and 112 participants from control villages.

At baseline, the knowledge of respondents was analysed using the scoring method whereby a respondent was considered to have high level of knowledge/safety practice or low level of knowledge/safety practice on a particular variable when his/her total responses scores were 6-10 points and 0-5 points, respectively. Also, binary logistic regression model was used to test for associations between categorical variables. The results indicated that, community level of knowledge on human *T. solium* taeniasis/cysticercosis was limited in the study area, whereby a total of 539 (61.8%) participants had low knowledge. Regarding preventive practices, it was found that, a total of 653 (74.9%) participants had low level of practices related to *T. solium* taeniasis/ cysticercosis transmission. A total of 572 (65.6%) participants had low level of knowledge and preventive practices related to human *T. solium* taeniasis/cysticercosis in the study area. However, it was further revealed that participants from Kongwa District were likely to have higher level of knowledge and preventive practices than those from Songwe District (OR=2.4). Also, participants with at least primary level of education were likely to have higher level of knowledge and preventive practices than those with informal level of education (OR=3.3). Further descriptive analysis and regression analysis were used, whereby at baseline a total of 12 (1.4%) individuals tested positive by Ag-ELISA indicating the presence of circulating antigen of *T. solium* cysticercosis (active infection). A total of 21 (2.4%) individuals were tested positive by WB-IgG assay indicating the presence of circulating IgG antibodies (exposure to infection). The seropositivity of both tests varied considerably across demographic, behavioural and clinical factors. Further analysis found that, participants who were above 45 years of age were more likely to be infected (OR=6.7) and among this group, 10 (2.8%) and 14 (3.9%) individuals were detected by Ag-ELISA and WB-IgG assay, respectively.

The effectiveness of the intervention was evaluated by comparing changes in knowledge, preventive practices related to human *T. solium* transmission and cumulative incidence of human *T. solium* cysticercosis between intervention and control villages using Sharpiro-Wilk test, T-test and Wilcoxon test. In addition, the cumulative incidences of HCC were compared between the intervention and control groups taking into account that all detected cases at the baseline were subjected to further clinical management

and were not included in the third phase of the study. At baseline, the study revealed no significant difference in knowledge and practices mean scores between the control and intervention villages (1.45 ±0.94 vs 1.54±1.02, p= 0.24). In addition, no significant difference was observed in the prevalence of human *T. solium* cysticercosis between intervention and the control villages (1.4% vs.1.4%, p = 0.97) by Ag-ELISA. At one year post intervention, the study revealed a significantly higher knowledge mean scores in the intervention villages compared to the control villages (2.06 ±1.45 vs 0.94 ±1.18, p < 0.001). However, there was no significant difference in the mean practice scores and cumulative incidences of human *T. solium* cysticercosis at the intervention compared to the control villages. A lack of improved preventive practices might be attributed by limited time to evaluate the effect and the observed insufficient supply of safe and clean water.

This study reveals that the community based health education intervention is effective in increasing knowledge on control of human *T. solium* infections. However, improvement in preventive practices and reduction in incidences of human *T. solium* cysticercosis are a gradual process, they may require sanitary and hygienic improvement and more time after the intervention to see the desired effect. Therefore, the study recommends implementation of this community based health education intervention to the general public for broader and permanent effect.

IKISIRI KUU

Mnyoo aina ya tegu husababaisha magonjwa kwa binadamu na nguruwe. Miongoni mwa magonjwa haya ni ugonjwa wa 'taeniosis' kwa binadamu na ugonjwa wa 'cysticercosis' kwa binadamu na nguruwe. Haya ni miongoni mwa magonjwa yasiyopewa kipaumbele duniani, na ripoti za kitafiti zinaonyesha uwepo wa madhara makubwa kwa binadamu kiuchumi, kiafya na kijamii katika jamii zilizoathirika na magonjwa haya. Hivi karibuni, magonjwa haya yameanza kupewa kipaumbele na yamejumuishwa kwenye mkakati wa kidunia wa mapamabano dhidi ya maambukizi ya magonjwa hatatarishi yasiyopewa kipaumble. Barani Afrika, hususani kusini mwa jangwa la Sahara ni miongoni mwa maeneo yalioathirika zaidi na maambukizi haya na jitihada zaidi zinahitajika ili kuzuia maambukizi haya. Tanzania ni miongoni mwa nchi zilizo kusini mwa jangwa la Sahara ambapo ripoti za kitafiti zimeonyesha kuwa imeathirika na maambukizi haya, hususani kwenye maeneo ya vijijini yanayojihusisha na ufugaji wa kiasili wa nguruwe. Miongoni mwa njia zinazoshauriwa kutumika ili kujikinga na maambukizi haya ni; kuimarisha usafi binafsi na usafi wa mazingira, kuzingatia kanuni bora za ufugaji wa nguruwe, ujenzi wa vyoo safi na salama, matumizi ya maji safi na salama na utoaji wa elimu ya afya na kujikinga dhidi ya maambukizi. Ripoti za kitafiti zimebaini kuwa elimu ya afya na kujikinga dhidi ya maambukizi ni msingi wa kujikinga na kuzuia magonjwa ya maambukizi sambamba na maambukizi ya mnyoo tegu kwani humpatia mlengwa na jamii maarifa na miongozo itakayomfanya kubadili tabia hatarishi na kufanya maamuzi sahihi kutatua changamoto zinazosababisha kuendelea kwa maambukizi katika jamii inayomzunguka sambamba na kujikinga dhidi ya maambukizi ya mnyoo tegu na maambukizi mengine. Hata hivyo ripoti za kitafiti nchini Tanzania zimeonyesha uwepo wa tafiti chache zilizofanyika kupima mafanikio ya elimu ya afya na kujikinga dhidi ya maambukizi ya magonjwa yanayosababishwa na mnyoo tegu katika maeneo yaliyoathirika Zaidi.

Hivyo basi, lengo la utafiti huu lilikuwa ni kupima mafanikio ya njia ya utoaji elimu ya afya na kujikinga dhidi ya maambukizi katika jamii zilizoathirika ili kuongeza ufahamu wa magojwa yatokano na maambukizi ya minyoo tegu,

kubadili tabia hatarishi zinazochangia maambukizi ya mnyoo tegu na kupunguza maambukizi mapya ya mnyoo tegu katika jamii shiriki. Ili kufanikisha lengo la utafiti huu, wilaya za Kongwa na Songwe zilichaguliwa kufanyiwa utafiti. Vijijini vyote ndani ya wilaya tajwa, zilihakikiwa kama zina vigezo husika ili kushiriki katika utafiti huu, lengo likiwa ni kuchagua vijiji arobaini na mbili (42) vya utafiti kama ilivyokuwa kwenye tafiti nyingine zinazolingana na tafiti hii iliyofanyika kaskazini mwa Tanzania. Hivyo jumla la washiriki 872 walichaguliwa kushiriki katika utafiti huu kutoka katika vijiji vya utafiti. Washiriki wote walichaguliwa kwa kufuata taratibu za kitafiti. Vijiji vilivyochaguliwa kushiriki viligawanywa katika makundi mawili, kundi elimishwa na kundi lisilielimishwa. Ili kufanikisha lengo, Utafiti huu ulifanyika katika awamu tatu. Awamu ya kwanza ilihusu ukusanywaji wa taarifa za awali kuhusu uelewa na tabia ya jamii kuhusu maambukizi ya minyoo tegu na ukubwa wa maambukizi ya mnyoo tegu kwa wilaya zote za utafiti. Awamu ya pili ilihusu kutoa elimu kwa jamii kuhusu maambukizi ya minyoo tegu na namna bora ya kujikinga. Na awamu ya tatu ilihusu kupima mafanikio ya elimu ya afya iliyotolewa katika kuongea uelewa na kuacha tabia hatarisha na kupunguza maambukizi ya magonjwa yatokanayo na mnyoo tegu katika jamii. Washiriki wote walitakiwa kushiriki kwenye awamu zote tatu za utafiti.

Awamu ya kwanza ilihusisha njia ya dodoso kukusanya taarifa kuhusu uelewa wa jamii juu ya maambukizi ya mnyoo tegu na namna ya kudhibiti maambukizi kwa binadamu. Washiriki wote kutoka vijiji vyote vya utafiti walishiriki, washiriki wapatao ishirini (20) kutoka kila kijiji walichaguliwa kushirika kwenye utafiti, na katika kila kaya mwanakaya mmoja tu alishiriki katika utafiti. Mshiriki aliombwa ridhaa yake kwa kujaza fomu maalumu kabla ya kushiriki utafiti huu, baada ya kuridhia alishiriki katika dodoso na kuchukuliwa kipimo cha damu na mtaalum wa maabara kutoka katika mshipa wa mkono ili kupima uwepo wa maambukizi ya mnyoo tegu (cysticercosis). Damu ilipimwa ili kuangalia vimelea vya mnyoo tegu katika mwili wa mshiriki kwa kutumi kipimo kinajulikana kama Ag-ELISA na Western blot IgG kit (WB-IgG).

Katika awamu ya pili, washiriki toka kundi la vijiji elimishwa walipewa elimu ya maambukizi ya mnyoo tegu na namna sahihi ya kujikinga dhidi ya maambukizi, pia walipewa elimu ya ufugaji bora wa nguruwe katika makazi yao. Elimu hii itolewa kwa vipindi maalum vilivyoandaliwa kitaamu. Elimu ilitolewa kwa utaratibu wa awali kuwaelimisha viongozi na wataalamu ngaji ya kata, Kijiji na vitongoji ili kuwajengea uwezo wa wao kuweza kuwaelimisha jamii wanazoziongoja. Baadae, viongozi wataalamu na watafiti walishirikiana kuelimisha washiriki wote 440 wa kundi la vijiji elimishwa na washiriki wengine 432 toka kundi la vijiji visivyoelimishwa walibaki bila kupewa elimu hii maalum. Awamu ya tatu ya utafiti ilifanyika mwaka mmoja baada ya awamu ya pili ya uelimishaji kukamirika. Katika awamu hii ya tatu, dodoso la awamu ya kwanza lilitumika kukusanya taarifa ya magonjwa ya mnyoo tegu na kipimo cha damu toka kwa kila mshiriki kilichukuliwa kama ilivyokuwa kwenye awamu ya kwanza ikihusisha washiriki walewale wa awamu ya kwanza na ya pili, hata hivyo jumla ya washiriki 210 hawakuweza shiriki tena kwenye awamu ya tatu kama ilivyopangwa kwa sababu mbalimbali. Hivyo basi, jumla ya washiriki 872 walishiriki kwenye awamu ya kwanza na washiriki 662 walishiriki awamu zote tatu.

Taarifa za utafiti huu zilikusanywa na kuchanganuliwa kwa njia mbalimbali za kitafiti na matokeo yalibaininshwa. Katika awamu ya kwanza, upimaji kuhusu uelewa wa maambukizi ya mnyoo tegu ulibaini kuwa jumla ya washiriki 539 (61.8%) wana uwelewa mdogo kuhusu maambukizi ya mnyoo tegu kwa binadamu. Utafiti pia ulibaini kuwa jumla ya washiriki 653(74.9%) walikuwa na tabia hatarisha zinazoweza changia maambukizi ya mnyoo tegu. Pia jumla ya washiriki 572 (65.6%) walikuwa na uwelewa mdogo na mazoea hatarishi yanaoweza kuendeleza maambukizi ya mnyoo tegu katika maeneo yao. Utafiti pia ulibaini kuwa washiriki toka wilaya ya Kongwa na washiriki wenye elimu ya msingi na zaidi wana nafasi kubwa Zaidi ya kuongeza uelewa na na kuboresha tabia hatarishi zitakazosaidia Zaidi katika kujikinga dhidi ya maambukizi ya mnyoo tegu. Kwenye awamu hii ya kwanza ya utafiti huu, matokeao pia yalibaini kuwa jumla wa washiriki 12(1.4%) walikuwa na maambukizi ya mnyoo tegu (cysticercosis) kwa kipimo cha Ag-ELISA na washiriki 21 (2.4%) walibainika kuwa na historia kupata maambukizi tajwa kwa kipimo cha WB-IgG. Utafiti pia ulibaini maambukizi kutofautia kadiri ya umri na washiriki wenye umri zaidi ya miaka 45 walikuwa kwenye hatari Zaidi ya kupata maambukizi. Ndani ya kundi hili utafiti ulibaini kuwa washiriki wapatao 10 (2.8%) walikutwa na maambukizi ya mnyoo tegu (cysticercosis) na washiriki wapatao 14 (3.9%) walikutwa na uthibitisho wa kuwahi kuwa na maambukizi haya. Njia ya kuelimisha jamii ili kuthibiti maambukizi ilitumika katika vijiji 21 kwenye kundi la vijiji elimishwa. Mafanikio ya elimu iliyotolewa kwenye vijiji vilivyoelimishwa yalipimwa kwa kulinganisha mabadiliko ya uelewa, mabadiliko ya tabia na mazoea hatarishi na uwepo wa tofauti ya maambukizi mapya ya mnyootegu (cysticercosis) kati ya kundi la vijiji vilivyoelemishwa na vijiji visivyoelimishwa. Uwepo wa maambukizi mapya ya mnyoo tegu (cysticercosis) uliangaliwa na kulinganishwa kati ya kundi la vijiji elimishwa na kundi la vijiji visivyoelemishwa, washiriki wote waliokutwa na maambukizi kwenye awamu ya kwanza hawakushirikishwa kwenye awamu ya tatu. Kwenye awamu ya kwanza ya utafiti huu, matokeo yameonyesha kuwa hakukuwa na tofauti ya uelewa na mazoea hatarishi kati ya kundi la vijiji elimishwa na kundi la vijiji visivyoelimishwa. Pia, kwenye awamu ya kwanza matokeo yameonyesha kutokuwepo na utofauti wa kiwango cha maambukizi ya mnyootegu (cysticercosis) baina ya makundi mawili ya vijiji (1.4% vs.1.4%, $p = 0.97$) kwa majibu wa kipimo cha Ag-Elisa. Matokeo katika awamu ya tatu ya utafiti yalipatikana mwaka mmoja baada ya kuelimisha kundi moja la vijiji. Utafiti ulibaini ongezeko la uelewa wa maambukizi ya mnyootegu na namna sahihi ya kujikinga katika kundi lilipewa elimu ukilinganisha na kundi lisilopewa elimu (2.06 ±1.45 vs 0.94 ±1.18, $p < 0.001$). Sambamba na matokeo hayo, utafiti pia ulibaina kutokuwepo na tofauti ya tabia na mazoea hatatirishi yanaweza kuchangia maambukizi kati ya makundi mawili ya vijiji. Vile utafiti ulibaini uwepo wa maambukizi mapya ya mnyootegu (cysticercosis) yanayofanana ($p>0.05$) kwenye makundi yote mawili ya vijiji licha ya elimu kutolewa kwenye kundi moja. katika kundi la vijiji visivyoelimishwa ilikuwa ni 6 (1.9%) na katika kundi la vijiji vilivyoeleimishwa ilikuwa ni 4 (1.2%).

Hivyo basi, matokeo ya utafiti yameonyesha kuwa ili kudhibiti na kuzuia maambukizi ya magonjwa yatokanayo na maambukizi ya mnyoo tegu, njia ya kuelimisha jamii kuhusu maambukizi na namana ya kudhibiti maambukizi, inasasaidia kuongeza uelewa endelevu kwa jamii. Hata hivyo ili kuboresha tabia na mazoea hatarishi, na kupunguza uwezekano wa maambukizi mapya, jitihada zaidi zinahitajika ikiwemo kuongeza muda wa kuelimisha na kutafsiri elimu inayotolewa, kuongeza na kuboreshwa miundombinu katika vijiji vyenye mazingira hatarisha ili kuvijengea uwezo wa kutafsiri uelewa kwa vitendo. Utafiti unapendekeza elimu hii iwe endelevu hususani kwenye maeneo yote yaliyobainika kuwa na maambukizi na yale yenye uwezekano wa kupata maambukizi. Vile vile elimu hii inapendekezwa kuwa na muendelezo kwenye shule, vituo vya afya na maeneo yenye mkusanyiko wa watu ili iweze kuwa na manufaa zaidi.

DECLARATION

I, George Isdory Makingi, do hereby declare to the senate of Sokoine University of Agriculture that, this thesis is my original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution for a degree award.

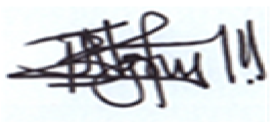
____

George Isdory Makingi 14.05.2023
PhD candidate **Date**

The above declaration is confirmed by;

____

14.05.2023
Dr. Jahashi Nzalawahe **Date**
1st Supervisor



14. 05. 2024
Dr. Bernard Ngowi **Date**
2nd Supervisor

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ACKNOWLEDGEMENTS

My sincere gratitude goes to all the people and institutions that assisted in different ways to complete my studies. I would like to take this opportunity to express my profound appreciation by mentioning a few vital contributors.

My first appreciation goes to my employer Sokoine University of Agriculture (SUA) for granting me the study leave and permission to use its facilities for this study. In the same strength, I would like to express my deep appreciation to the Cystinet-SUA project for sponsoring this interdisciplinary research study on poverty-related and neglected diseases with funding from the German Federal Ministry of Education and Research.

My heartfelt appreciation goes to Prof. Helena Ngowi of the SUA for expressing her trust that I could undertake this study effectively. Five years down the line, I am glad that I have finally achieved my goal. In that regard, I also thank Dr. Ernatus Mkupasi for his input and advice when we were on the drawing board, and for being ready to assist all the time. To my PhD supervisors; Dr. Jahashi Nzalawahe of the SUA and Dr. Bernard Ngowi from the University of Dar-es-salaam for grooming me into a researcher, a task which was so sacrificial. I am so grateful to my supervisors.

Many other thanks go to my research assistants; Grace Isdory, Baraka Edson, Fatna Kivava, Amina Abdallah and Kinyala Lyandala for their support during the field and laboratory work.

Special thanks are extended to participating households from Kongwa and Songwe Districts who willingly offered their valuable time to participate in the study, as well as all stakeholders and partners including District Veterinary Officers, Medical Officers and village local leaders for their support.

I deeply thank my family for their love and encouragement which enabled me to pursue this study. In a very special way, I would like to thank my mother Bertha Makingi and my late father Isdory Makingi for raising me into who I am and for educating me to this level. May the soul of my father Rest in peace.

As it may not be possible to mention everyone, all contributions to this work are highly appreciated.

DEDICATION

This thesis is dedicated to my mother, Bertha Makingi and my late father Isdory Makingi.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PAPERS

LIST OF APPENDICES

LIST OF ABBREVIATIONS AND SYMBOLS

Ab	-	Antibody
Ag	-	Antigen
Ag-ELISA	-	Antigen based Enzyme Linked-Immunosorbent Assay
CI	-	Confidence Interval
CNS	-	Central Nervous system
CSF	-	Cerebral Spinal Fluid
CT	-	Computerized tomography
DALY	-	Disability Adjusted Life Year
DNA	-	Deoxyribonucleic acid
ELISA	-	Enzyme-linked immunoassay
EUR	-	Euro
FAO	-	Food and Agriculture Organization of the United Nations
GBD	-	Global Burden of Disease
HCC	-	Human cysticercosis
IgG	-	Immunoglobulin G
M	-	Meters
MDA	-	Mass Drug Administration
Ml	-	Millimeters
MRI	-	Magnetic Resonance Imaging
NCC	-	Neurocysticercosis
NIMR	-	National Institute for Medical Research
NTD	-	Neglected Tropical Diseases
PCC	-	Porcine Cysticercosis
PCR	-	Polymerase chain reaction
RFLP	-	Restriction fragment length polymorphism
SPSS	-	Statistical Package for Social Sciences
SSA	-	Sub-Saharan Africa
SUA	-	Sokoine University of Agriculture
TSTC	-	*Taenia solium* taeniosis cysticercosis
URT	-	United Republic of Tanzania
USA	-	United States of America
USD	-	United States Dollar
WASH	-	Water, Sanitation and Hygiene
WB	-	Western Blot

WOAH	-	World Organization for Animal Health
WHO	-	World Health Organization

CHAPTER ONE

1.0 INTRODUCTION

1.1 General Introduction

Taenia solium, a zoonotic tapeworm causes two distinct diseases, cysticercosis that affects humans and pigs and taeniasis in humans only. Taeniasis refers to human intestinal infection with adult *T. solium*, while cysticercosis is the development of larval cysts in the tissues of humans and pigs. Human cysticercosis (HCC) occurs when someone ingests food or water contaminated with tapeworm eggs excreted by human adult tapeworm carriers. Human cysticercosis sometimes occurs due to self-infection when *T. solium* eggs in the human intestine raptures into larvae. The eggs develop into larvae and lodge in form of cyst in the muscles of the body and eyes. The larva may further invade and lodge in the central nervous system (CNS) leading to neurocysticercosis (NCC), which is clinically presented with seizures, epilepsy and death (WHO, 2016). *T. solium* cysticercosis was added by World Health Organization (WHO) to the list of neglected tropical diseases (NTD) in 2010 due to its public health importance. Similarly, in 2014 Food and Agriculture Organization of the United Nations (FAO) has ranked the disease as the number one parasitic zoonosis (FAO and WHO, 2014).

Taenia solium represents a substantial burden because of its impact on human health, animal health and welfare as well as economic losses due to disability and loss of pig productivity (Phiri *et al.*, 2003; Ngowi *et al.,* 2004; Carabin *et al.,* 2006; Nkwengulila, 2014; Trevisan *et al.,* 2017). *Taenia solium* taeniasis/cysticercosis (TSTC) is endemic where prevailing cultural, socioeconomic, and sanitary conditions permit completion of the parasite's life cycle in pigs and humans (Pawlowski, Allan and Sarti, 2005). About 50 million people worldwide are estimated to be infected with *T. solium* and 50 000 people die annually due to cysticercosis (Meštrović *et al.,* 2012).

The infections have worldwide distribution and are endemic in most parts of sub-Saharan African countries (SSA), South and Central America and parts of India (Winkler *et al.,* 2009; Kay, Prüss and Corvalán, 2000). The parasite is infrequently reported in most part of

Europe (Overbosch *et al.,* 2002; WHO and FAO, 2005). However, the increased international immigration and travel, has also increased chances of locally acquiring *T.solium* infections in some regions of Europe (Fabiani and Bruschi, 2013).

1.2 Morphology of *T. solium*

T. solium is flat, segmented and hermaphrodite, measuring between 2 to 6 m, the adult stage is composed of a head or scolex with a diameter of approximately one millimetre bearing four muscular suckers for fixation and allowing some form of locomotion (Flisser, 2013). The *T. solium* scolex has an armed rostellum, bearing between 22 and 36 hooks ordered in two rows. Following the scolex is a thin neck measuring approximately 5 to 10 mm, constituting portion with most of the biokinetic activity (Rodriguez Hidalgo, 2007) from this part the entire body or strobila is formed. The strobila constitutes of an average of 1000 proglottids or segments, which can be grouped as immature, mature and gravid segments. Immature segments are wider transversely than longitudinally and mature segments are square with primary sexual organs completely formed. The gravid segments have a rectangular shape with primary genital organs atrophied and entirely filled with a branched uterus packed with spherical eggs. The eggs measure between 30-35 micrometers in diameter composed of a chorionic membrane, a thick and grooved embryophore, which is formed by embryophoric blocks, an embryophoral membrane, two oncospheral membranes surrounding the oncosphere bearing three pairs of hooks. The eggs are fairly resistant to external environmental conditions and to common disinfectants. In humid and shady grounds and traditional systems for treating wastewater, eggs can remain viable for weeks or months (Rodriguez, 2007b). Taeniidae possess neither a coelomic cavity nor a digestive system, exchange of nutrients and metabolites occurs mostly through the tegument. An excretory system is formed by longitudinal lateral channels running through each segment with transverse connections. Each segment has an osmo-regulatory system and a nervous system and muscular fibres, allowing rhythmic and co-ordinated movements (White, 2000) .

1.3 Biological cycle of *T. solium*

T. solium has a two-hosts life cycle, whereby human is the only definitive host that harbor the adult parasite also the dead end intermediate host and pig acts as intermediate host. Humans harbour the adult *T. solium* in the intestines (taeniasis) that is acquired by eating raw or undercooked porcine cysticercosis (PCC) infected pork whereby the parasite attaches to the bowel wall by its suckers and hooks. Gravid proglottides are frequently detached from the distal end of the worm and are excreted in feces. Each proglottid contains 50,000 to 60,000 fertile eggs, which can remain viable for a long time in water, soil and vegetation. Pigs get infected through ingestion of feeds/or drinking water contaminated with *T. solium* eggs. Once ingested, the invasive oncospheres (embryos) in the eggs are liberated by the action of gastric acid and intestinal fluids and actively cross the bowel wall, enter the bloodstream, and are carried to the muscles and other tissues where they develop into larval vesicles or cysticerci causing PCC. Human can also be infected with the cysts by accidental ingestion of *T. solium* eggs through drinking contaminated water, eating undercooked vegetables contaminated with eggs or by contact with the feces containing eggs and develop HCC (Garcia and Del Brutto, 2000 and WHO, 2016). The mechanism by which oncospheres cross the bowel wall and lodge in human tissues is the same as that described in pigs. In human, cysts may also lodge in CNS causing ocular cysticercosis and NCC (WHO and FAO, 2005).

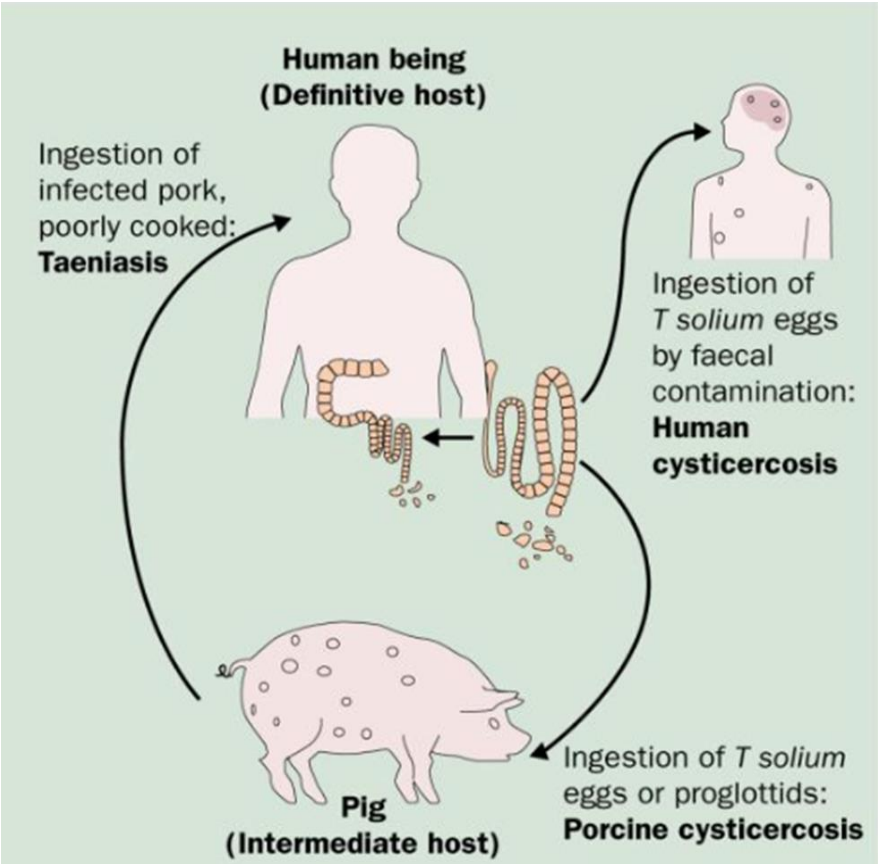

Figure 1.1: Life cycle of *Taenia solium* (García *et al.,* 2003)

1.4 Geographical distribution and burden of *T. solium* infections

Taenia solium has a global distribution (Fig. 2), reported in all the six regions of the world as categorized by the World Health Organization (WHO, 2016). However, the parasite is mostly prevalent in low-income countries where there is poor hygiene, inadequate sanitation and pig husbandry practices include free ranging (Garcia and Del Brutto, 2000; Flisser *et al.,* 2003). The *T. solium* infections are mostly prevalent in SSA (Phiri *et al.,* 2003; Zoli *et al.,* 2003; Braae *et al.,* 2015), South and Southeast Asia (Rajshekhar *et al.,* 2003; Braae *et al.,* 2018) and Latin America (García *et al.,* 2003a; Braae *et al.,* 2017b). Given that, poor regions of the world are most affected by the parasite, it is even considered as a biological marker of socio-economic underdevelopment (Murrell *et al.,* 2005). The infections have also been diagnosed in developed countries due to increased immigration and travel of *T. solium* carriers from endemic areas (Gonzalez *et al.,* 2003; Schantz and Tsang, 2003). For example, most of HCC cases reported in the USA are found in the states bordering Mexico, in which *T. solium* is known to be endemic (Hotez *et al.,* 2008).

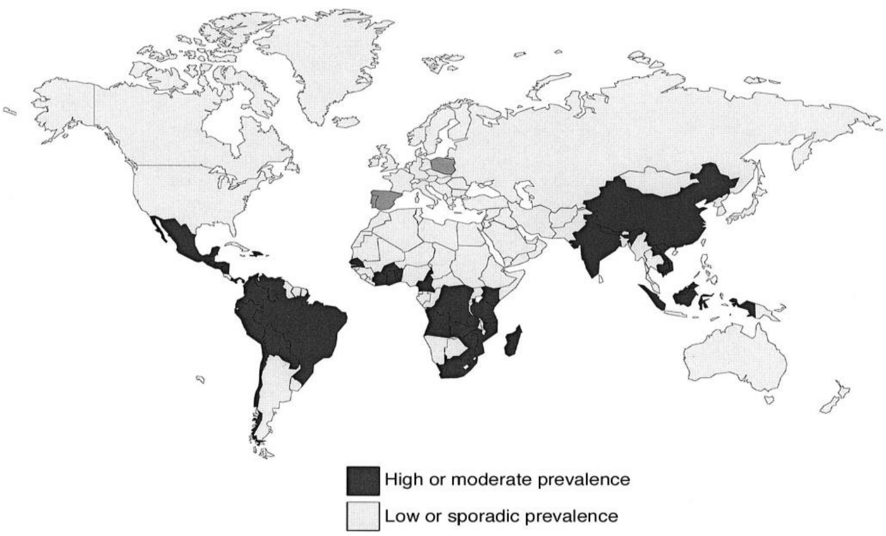

Figure 1.2: Global distribution of *Taenia solium* infections (WHO, 2016)

1.5 Burden of human *T. solium* infections

The burden of *T. solium* infections is mainly due to public health effects of NCC and economic losses due to associated treatment. The World Health Organization estimated that *T. solium* infections affect approximately 50 million people and about 50,000 of the victims die annually (WHO, 2016). Recent estimates of HCC showed an average sero-prevalence of 4% in Asia and 7% in Latin America and Africa (Coral-Almeida *et al.,* 2014, 2015). In Tanzania, the reported sero-prevalence of HCC is 16%-17% (Mwang'onde, Nkwengulila and Chacha, 2012; Mwanjali *et al.,* 2013). Based on the multi-criteria ranking for risk management of foodborne parasites, *T. solium* was ranked as the most important foodborne parasite, as NCC was considered to be the major cause of deaths from food-borne diseases

(WHO/FAO, 2014). In 2013, a study on the Global Burden of Diseases (GBD) estimated that there were 1,030,800 cases of HCC worldwide (GBD, 2017). In South Saharan Africa, it is estimated that about 1.9 to 6.2 million people are infected with *T. solium* and about 2.46 million may be suffering from NCC-associated epilepsy (Winkler, 2012). In *T. solium* endemic areas, NCC is believed to be responsible for about 14.2% to 50% of the acquired epileptic cases (Preux and Druet-Cabanac, 2005; Ndimubanzi *et al.,* 2010), and when access to health services is limited, mortalities due to NCC is reported to be up to six times higher than in the general population (WHO, 2015). Epilepsy is a major problem in SSA countries and may often be diagnosed and associated with NCC (Ndimubanzi *et al.,* 2010; Quet *et al.,* 2010). Although there is a significant association between HCC and epilepsy in Africa (Quet *et al.,* 2010), more studies are needed for the understanding of the various causes of epilepsy.

Similarly, limited data are available about the prevalence of adult tapeworm carriers (taeniasis) who are the source of HCC and PCC. The major difficulty for carrying out studies on taeniosis, is the lack of a simple and sensitive diagnostic test which is able to distinguish *T. solium* from other cestodes (Dorny *et al.,* 2003; Dorny, Brandt and Geerts, 2004). NCC resulting in epilepsy possess considerable health and economic burden in developing countries (Braae *et al.,* 2015; Carabin *et al.,* 2015) leading to disproportionate economic suffering in underprivileged populations (WHO, 2016; Gabriël *et al.,* 2017). Reports from most parts of SSA show that epileptics also suffer from discrimination, stigmatization, joblessness and disability (Carpio, Escobar and Hauser, 1998; Flisser *et al.,* 2003; Carabin *et al.,* 2006). Negative attitudes and behaviors toward epileptics by the general population are due to ignorance and mistaken perceptions. Some people believe that epilepsy is caused by witchcraft, which it is directly contagious, and sufferers therefore often seek treatment from herbalists, faith healers or witch doctors (Chacha *et al.,* 2014; Osakwe *et al.,* 2014). Surveys conducted in several African countries in both urban and rural areas, observed that epilepsy is still widely considered to be caused by witchcraft, hence epileptic people are afraid to reveal their status and may lose the opportunity to access medical treatment (Nyame *et al.,*1997; Millogo *et al.,*2004).

1.6 Risk factors for transmission of *T. solium* infections

T. solium infections have been recognized to be common in rural communities in the developing world. Various factors have been identified to facilitate transmission of the infections in humans and pigs. Such factors include; poor hygiene and inadequate sanitation practices in humans, free-range pig rearing and tethering, lack of knowledge about the disease and its transmission dynamics and lack or insufficient pork inspection (Garcia and Del Brutto, 2000; García *et al.,* 2003; Murrell, Weltgesundheitsorganisation and FAO, 2005).

1.6.1 Risk factors for taeniasis transmission

Taeniasis (transmission from pig to human), is acquired through consumption of under-cooked or raw pork with viable/infective cysticerci, which happen when pork inspection is lacking or insufficient (Murrell *et al.,* 2005; Kyvsgaard *et al*., 2007; Coral-Almeida *et al.,* 2015). In many endemic areas, most of the pigs are kept by smallholder farmers where pigs are commonly slaughtered at home and pork inspection is lacking or done insufficiently. Studies in Tanzania have shown that males are at a higher risk of acquiring the infection than females; and risk of infection transmission increases with age (Mwanjali *et al*., 2012; Braae *et al.,* 2016b, 2017a). This could be because in many endemic rural areas, pork is mostly consumed in local bars which are mostly attended by adult males. Pork barbequing is a common method of preparing, mentioned to be one of the risk factors for taeniasis, as it does not assure enough core temperature to kill the cysticerci (Boa *et al.,* 2003; Maridadi, Lwelamira and Simime, 2011).

1.6.2 Risk factors for human cysticercosis transmission

The major risk for HCC is poor hygiene and inadequate sanitation that leads to consumption of food or water contaminated with *T. solium* eggs from human carrier (Mwape *et al.,* 2012; Mwanjali *et al.,* 2013). Insufficient or improper hand washing after latrine use and before eating can lead to transmission of the parasite eggs. Hands washing by dipping instead of using running water was found to be associated with transmission of HCC (Mwanjali *et al.,* 2013). Poor or lack of latrines and consumption of contaminated fruits and vegetables have also been identified as risk factors (Secka *et al.,* 2011; Noormahomed *et al.,* 2003). In endemic areas, lack of safe drinking water and consuming raw vegetables were identified as the main risk factors (Prasad *et al.,* 2007; Mwanjali *et al.,* 2013). Some studies have found that the risk of HCC increases with age, most probably because of more exposure to the infections (Praet *et al.,* 2010b; Mwanjali *et al.,* 2013, 2013; Carabin *et al.,* 2015; Coral-Almeida *et al.,* 2015). However, anybody coming in contact with a tapeworm carrier can be infected, which means that people who do not consume pork because of cultural or religious reasons are also at risk (Carabin *et al.,* 2015).

1.7 Clinical presentations of human *T. solium* infections

1.7.1 Taeniasis

Taeniasis is usually asymptomatic, although carriers report gastrointestinal disturbances, such as nausea, vomiting, constipation, diarrhoea, increased appetite, abdominal pain and distension (Sciutto *et al.,* 2000). According to Muller (1975) these symptoms might be due to excretions produced by the parasite. However, the most noticeable sign of taeniasis is the presence of proglottids in human faeces. (Flisser, Rodríguez-Canul and Willingham, 2006).

1.7.2 Human cysticercosis

Clinical presentations of HCC are variable depending on location, number, stage of development of the cysticerci, as well as host's immune response. Infected individuals may remain asymptomatic for months or even years, because viable cysticerci have the ability to evade host's immune response hence preventing an inflammatory reaction (Sciutto *et al.,* 2007). Symptoms commonly arise when cysticerci degenerate causing an immune mediated inflammatory response around the cysticerci. The HCC in the central nervous system leads to NCC which is always presented by the most severe form of the disease (Carabin *et al.,* 2011; Kelvin *et al.,* 2011). The most severe clinical signs of the disease are observed when the cysticerci lodge in the sub-arachnoid space or the ventricles. The most common presenting signs of NCC are epileptic seizures, which may be simple or complex, partial or generalized. Other signs include acute or chronic headache, dizziness, nausea, hydrocephalus, meningitis, psychosis, ataxia, dementia, strokes, and increased intra-cranial pressure (García *et al.,* 2002; Carabin *et al.,* 2011; Garcia, Nash and Del Brutto, 2014). In extreme cases, encephalitis may occur with severe consequences including death (Mafojane *et al.,* 2003).

1.8 Diagnosis of human *T. solium* taeniasis/cysticercosis

A number of diagnostic options are available for human TSTC. However, the main challenge in diagnosis has limited availability of affordable, optimally sensitive and specific diagnostic tools suitable for large scale use in the field setting (WHO, 2016; Johansen *et al.,* 2017).

1.8.1 Diagnosis of taeniasis

Several methods have been described to detect *T. solium* taeniasis. Macroscopic diagnosis is based on the search of gravid segments in the faeces or on the recovery of the worm after treatment with praziquantel and niclosamide (Sarti and Rajshekhar, 2003). Routine diagnosis is based on the microscopic detection of *Taenia* spp. Oncospheres or eggs in direct smears or after concentration methods such as the Kato-Katz and formol-ether methods. These methods have a sensitivity of around 38% to 60% (Rodriguez, 2007). In order to improve the detection of taeniasis cases, immunodiagnostic assays on faecal or sera samples have been developed with a great improvement in sensitivity and specificity. Copro-antigen diagnostic method, based upon the detection of parasite specific secretory antigens, was first reported in the 1960’s although did not gain widespread scientific attention until the 1980’s (Allan *et al.,* 2003). Specific secretory antigens are produced independently from reproductive materials and are therefore not reliant on active shedding of eggs or proglottids. Coproantigen ELISA has now been used in a variety of situations to detect adult *Taenia* carriers (Thomas, 2014). The copro-Ag ELISA currently available are not species specific, detecting both *T. solium* and *T. saginata* and cross-reactions have been reported with a variety of other gastro-intestinal parasites (Rodríguez *et al.,* 2003). Another ELISA was developed describing the use of specific *T. solium* antigens to detect antibodies in serum by Western blot with sensitivity and specificity rates of 95% and 100%

respectively (Wilkins *et al.,* 1999). Diagnosis of taeniasis by serological examination has obvious advantages over the feces-based methods. Example, species-specific diagnosis, avoidance of the potential biohazard and cultural unacceptability of collecting and handling faeces and also the possibility to combine this test with other immunological assays in the diagnosis of HCC. However, residual antibodies from past exposure might result in false positives (Allan *et al.,* 2003; Ito and Craig, 2003).

1.8.2 Diagnosis of human *T. solium* cysticercosis

Diagnosis of HCC involves use of immunodiagnostic methods developed to detect either circulating antigens of cysticerci of *Taenia* spp. or antibodies directed against circulating antigens in serum and CSF of human (Dorny, Brandt and Geerts, 2004; Garcia *et al.*, 2005). Several tests have been developed for antibody detection, using crude or purified antigens of *T. solium* cysticerci or synthetic peptides. The tests includes the enzyme-linked immunosorbent assay (ELISA), immunoblot techniques, radioimmunoassay, complement fixation test, dipstick assay and latex agglutination test (Deckers and Dorny., 2010 and Dorny *et al.,* 2003).These tests have varying degrees of sensitivity and specificity (Ferrer *et al.,* 2005). To overcome the fact that the presence of antibodies does not constitute direct evidence of existence of live parasite, antigen-based assays based on polyclonal and monoclonal antibodies have been developed (Singh and Prabhakar, 2002). The application of ELISA technique for detection of circulating parasite antigens presents some diagnostic advantages since it does not demonstrate exposure but identifies active infections (Dorny *et al.,* 2003). The most specific test developed is the Enzyme linked Immunotransfer blot (EITB), an immunoblot of seven cysticercus with specificity close to 100% and a sensitivity of around 90% (Tsang, Brand and Boyer, 1989; Ito and Craig, 2003).

1.8.3 Imaging methods

The frequently used imaging tools for diagnosis of HCC and NCC are the Computerized Tomography (CT) and the Magnetic Resonance Imaging (MRI) scans. They identify vesicular (viable), colloidal (degenerating) and calcified cysticerci or lesions related with cysticercosis in the CNS and skeletal muscle. They are useful diagnostic tools, however, in many developing countries, neuro-imaging methods are inaccessible and or too expensive for the rural population at risk limiting their application (Dorny *et al.*, 2003). Studies to compare the two imaging techniques have concluded that MRI is more sensitive and specific for identifying most forms of NCC (García *et al.,* 2000; Deckers and Dorny, 2010; Del Brutto *et al.,* 2017). Another drawback of the imaging tools is the need for specialized equipment and expertise, further limit their use particular in developing countries (García and Del Brutto, 2003). Although CT and MRI findings are highly suggestive of NCC, in some cases other infectious or neoplastic diseases may present similar lesions to that of NCC, making confirmatory diagnosis difficult. In such cases, a combination of clinical presentations, serology diagnostic methods and neuro-imaging may be needed to make a correct diagnosis (García *et al.,* 2000; Deckers and Dorny, 2010). As clinical manifestations of NCC are not specific, the correct diagnosis of NCC requires use of multiple diagnostic tools, and using a set of criteria (Del Brutto *et al.,* 2001; 2012; 2017).

1.8.4 Molecular methods

In order to overcome limitations in the identification of *Taenia* species based on morphology or detection of viable antigens or antibodies, various molecular approaches have been developed (Rodriguez., 2007). The molecular techniques commonly used for detection and differentiation of *Taenia* species using gDNA and/or mtDNA include Dot Blot analysis (Chapman *et al.,* 1995), Multiplex-PCR (González *et al.,* 2000, 2002), PCR-Restriction Fragment Length Polymorphism (RFLP) (Mayta *et al.,* 2000; González *et al.* 2002), a based excision sequence scanning thymine-base reader analysis (Yamasaki *et al.,* 2004) and random amplified polymorphic DNA (RAPD) (Eom *et al.,* 2002, 2011; Vega *et al.,* 2003). PCR-RFLP and multiplex-PCR permit differential diagnosis of *T. saginata*, *T. s. asiatica* and *T. solium*, even when examination by morphology cannot be performed, because these methods do not rely on the availability of intact gravid proglottids. Molecular techniques can be applied on fresh, frozen or ethanol-preserved parasitic material. Molecular methods are mostly used for confirmation in case of suspicious cysticerci species

(Rodriguez-Hidalgo *et al.,* 2002; Rodriguez, Wilkins and Dorny, 2012).

1.9 Treatment of human *T. solium* infections

1.9.1 Taeniasis

Treatment of taeniasis involves the use of anthelminthics such as praziquantel, niclosamide and albendazole (Garcia, Nash and Del Brutto, 2014). The treatment can be done on an individual basis, or as preventive chemotherapy depending on the local circumstances and the control approaches being implemented. Taeniasis can be treated with single doses of praziquantel (10 mg/kg) or niclosamide (adults and children over 6 years: 2 g, children aged 2–6 years: 1 g). Albendazole at 400 mg for 3 consecutive days has also been used. Recommendations and important considerations for the use of these drugs for preventive chemotherapy for taeniasis, are described in the WHO guideline for preventive chemotherapy to control *T. solium* taeniasis (WHO, 2005).

1.9.2 Human Cysticercosis

Treatment of human (neuro) cysticercosis continues to be controversial (Allan *et al.,* 2003). There is no standard regimen for the treatment of NCC and the treatment varies depending mainly on the number, size, location and developmental stage of the cysts, their surrounding inflammatory oedema, acuteness and severity of clinical symptoms or signs (WHO, 2021). Currently, management of NCC includes the use of symptomatic medication (including anticonvulsants), anti-inflammatory drugs, anti-parasitic drugs or surgery (Murrell, 2005). Always, treatment is not indicated because there are immediate risks of neurologic symptoms due to the acute inflammation that results from the death of cysts, and because cysts often die naturally within a short period (Garcia *et al.,* 2004). Therefore, some consensus guidelines were produced which indicate whether or not patients have to be treated (WHO, 2021). These guidelines were developed to assist health-care providers in appropriate, evidence-based management of parenchymal NCC. The guidelines do not address other forms of NCC and do not include management of extra-parenchymal disease (including cysticerci in the cerebral ventricles or subarachnoid space). The aim of the guidance is to improve decision-making to ensure appropriate patient care and to avoid misdiagnoses and inappropriate treatment of patients with NCC. The guidelines were developed in a collaboration between the WHO departments of Control of NTD and Mental Health and Substance Use (WHO, 2021).

1.10 Control and prevention

Regarding prevention and controlling human *T. solium* infections, several measures have been formulated. The measures currently available for control include elimination of infected pigs, meat inspection, improvement of sanitation, improvement of hygiene and pig husbandry, health education, treatment of intestinal taeniasis, chemotherapy of infected pigs and mass treatment in humans (WHO and FAO, 2005).

1.10.1 Health education

Health education is regarded as the corner stone control measure in obtaining the commitment and continuing involvement in a prevention and control program. For any intervention to be sustainable, full participation of the community is highly required (WHO/FAO/OIE, 2004). Community knowledge, behaviour and practices play an important role in the transmission of *T. solium* infections. Health education improves knowledge about *T. solium* transmission cycle, which is expected to influence change in behaviour and practices with an ultimate decrease in prevalence and incidence of *T. solium* infections. Health education could play a significant role by informing the community about transmission dynamics and risks related to poor hygiene, inadequate sanitation and improper pig rearing systems (Fleury *et al*., 2013; Lightowler *et al*., 2013; Thomas, 2015; Gabriel *et al*., 2016). Impact of the intervention could extend throughout the health workers and general population (Thomas, 2015), although like other interventions, education has limitations as a stand-alone approach (Lightowlers, 2010; Gabriel, *et al*., 2016). Several studies have demonstrated the importance of health education in the control of *T. solium* infections (Sarti *et al.,* 1997; Ngowi *et al.,* 2008; Ngowi *et al.,* 2011; Alexander *et al.,* 2012; Mwidunda *et al.,* 2015; Ertel *et al.,* 2017; Carabin *et al.,* 2018; Hobbs *et al.,* 2018). However, only few studies have actually assessed an impact of health education on the prevalence or incidence of *T. solium* infections. Ngowi *et al.* (2008) observed a decrease in the incidence of PCC about one year after a health education intervention, as assessed by Ag-ELISA using sentinel pigs. Another study in Mexico showed health education could significantly decrease prevalence of PCC measured by EITB one year after the intervention (Sarti *et al.,* 1997). Other studies in Burkina Faso, Carabin *et al.* (2018) showed that a community-based educational intervention was effective in reducing the incidence and prevalence of HCC. In these studies, the increase in knowledge did not significantly change observed behaviour. One of the reasons for less observed change in behaviour after an improvement in knowledge has been mentioned to be limited resources to translate the knowledge into practice (Sarti *et al.,* 1997). This suggests that health education should be supplemented with other interventions for long-term sustainability (Murrell *et al.,* 2005). For easy translation, health education intervention needs to be provided by well trained personnel and will be more effective if it is associated with identification and treatment of tapeworm carriers (Flisser and Lightowlers, 2001). However, further studies are required to assess effectiveness of health education intervention for control and prevention of *T. solium* infections, especially when it is provided as the only intervention (Lightowlers, 2013).

1.10.2 Improving sanitation and personal hygiene

Provision of basic sanitary facilities and improvement of personal hygiene is a first step in the prevention of a number of faecally transmitted diseases including *T. solium* infections. There has been an ongoing campaign for integration of water, sanitation and hygiene (WASH) infrastructure for sustainable control or eradication of many NTDs (Freeman *et al.,* 2013). However, community involvement is essential for sustainable and successful community programme to improve sanitary and personal hygiene, and any intervention should be accompanied by a health education to increase awareness of the communities on the disease and the benefits of the control programmes. In addition, sanitation programmes should be tailored to the local settings by accommodating socio-economic and cultural factors within the communities. Some cultural practices regarding use of latrines have been mentioned as one of the reasons for lack of use of latrines by adult males in Zambia and in Kenya (Levy *et al.,* 2010a; Thys *et al.,* 2016). This should be taken into consideration when addressing sanitation programmes. The benefit of sanitation measures isn't only for control of *T. solium*, but also for controlling other infectious diseases which cause substantial morbidities and mortalities among children (Brooks *et al.,* 2006). Therefore, improvement of sanitation and personal hygiene fits within the broader of One Health approach and this will improve adoption and compliance by the communities.

1.10.3 Improved pig husbandry practices

A number of critical factors related to the rearing of pig must be monitored to ensure prevention of various infections. Pig keepers should be advised to stop free ranging system to prevent their pigs from having contact with human feaces or materials contaminated by feaces, slaughter pigs at the slaughter slabs and the pork be inspected before selling, clean all tools used to cut the meat in order to prevent the transfer of cysticerci (Cao *et al.,* 1997; Gonzalez *et al.,* 2003). Free roaming pigs are considered to have an increased access to human faeces, especially in areas where disposal of faeces is not proper (Gonzalez *et al*., 2003). Confining pigs will reduce the possibility of access to human faeces, unless defecation is practiced within the confinement area or pigs are deliberately provided with human stool (Flisser *et al*., 2003) or transmission occurs through contaminated feed or water (Braae *et al.*, 2015a; Komba *et al*., 2013). A decline in prevalence of PCC was observed following a health education campaign which resulted in fewer free-roaming pigs (Sarti *et al.,*2003). However, as some studies have shown the possibility of transmission within the confinement as a result of providing pigs with contaminated feeds and water (Komba *et al.,* 2013; Braae *et al.,* 2015), the importance of providing confined pigs with clean and safe feed and water should be emphasized.

1.10.4 Vaccination of pigs

Another approach for the controlling *T. solium infections* in human is the use of *T. solium* vaccines in pigs. Some progress has been made in this area. A number of vaccines candidates have been developed and tested for efficacy against PCC, such as SP3Vac, TSOL45 and

TSOL18. However, SP3Vac and TSOL18 appear to have a potential to control PCC as they provide a high degree of protection (Huerta *et al.,* 2001; Morales *et al.,* 2008). The final objective is to develop inexpensive and highly effective vaccine which can prevent *T. solium* in neonates as well as in old pigs, and which can be administered orally without the need for equipment or trained personnel (Lightowlers, 2010). A recombinant protein (TSOL18) which is expressed in the oncosphere stage of life cycle was found to be the most effective, by providing complete protection both in controlled laboratory trials (Flisser *et al.* 2004; Gonzalez *et al.* 2005; Lightowlers, 2010) and in field trials (Assana *et al.,* 2010; Poudel *et al.,* 2019). The TSOL18 is commercially produced by India immunologicals Limited and the registration process for use in other countries is on-going. Despite the reported efficacy in protecting pigs against the infection, TSOL18 does not affect established *T. solium* infection, and this is the rationale for using it concurrently with Oxfendazole. However, in endemic areas of SSA including Tanzania, no vaccines are currently available for pigs (Kabululu *et al.,* 2020).

1.11 Problem statement and justification

Studies on *T. solium* infections in human have been done in Tanzania, and the infections have been reported in some areas with significant health, economic and social impact, requiring urgent attention to prevent using multisectoral and sustainable approaches (Ngowi *et al.,* 2010, 2019; Mwanjali *et al.,* 2013; Mwang'onde, Nkwengulila and Chacha, 2014). A study conducted to assess the prevalence of HCC in general public in Mbulu District, found about 16.3% of the community members were infected with HCC (Mwang'onde, Nkwengulila and Chacha., 2012). Another cross-sectional community-based survey on the prevalence of HCC and taeniasis conducted in Mbozi District found more than 15% of people had active HCC indicating a high level of environmental contamination with *T. solium* eggs. This was supported by further finding whereby 4% of the people were detected with *T. solium* tapeworms (Mwanjali *et al.,* 2013). In Tanzania, the number of disability-adjusted life years (DALYs) per thousand person years for NCC-associated epilepsy was estimated to be 0.7 for the year 2012. The annual number of NCC-associated epilepsy incident cases and deaths were 17,853 and 212, respectively (Trevisan *et al.,* 2017). Additionally, around five million USD were spent due to NCC-associated epilepsy, comprising direct and indirect costs due to hospitalizations, visits to the hospitals/doctors and the cost of drugs/medicines (WHO, 2016). Furthermore, studies have demonstrated a strong association between *T. solium* infections and some social practices such as poor hygiene, improper sanitation, inability to recognize infected human and insufficient knowledge on transmission (Ngowi *et al.,* 2008; Pandian *et al.,* 2011; Sankhyan, Gupta and Singh, 2015; Millogo *et al.,* 2019; Nyangi *et al.,* 2022). These studies provide evidence that the parasite is widespread and control efforts at local, regional and national levels should be initiated using appropriate and sustainable approaches to decrease or eliminate the burden of the infections (Ngowi *et al.,* 2010, 2019; Mwanjali *et al.,* 2013; Mwang'onde, Nkwengulila and Chacha, 2014).

Control measures recommended to combat the infections include improvements in hygiene, sanitation, pig management, mass taeniacidal chemotherapy and health education (WHO and FAO, 2005). However, there are limited community studies on the evaluation of such interventions in endemic countries, including Tanzania (Ngowi *et al.,* 2008, 2009). Health education is an important strategy adopted in many countries to prevent transmission of TSTC and other infections in communities (Kang *et al.,* 2012; Bati, Legesse and Medhin, 2013; Bisallah *et al.,* 2018; Balami *et al.,* 2019; Wang and Fang, 2020). In Tanzania health education intervention study was done in Mbulu District (Ngowi *et al.*, 2008), the impact was evaluated showing a drop of 43% in PCC prevalence (Based on Ag-ELISA), also an increase in disease knowledge. Another study carried in the same district, assessing the effect of health education provided to primary and secondary school children in form of an address by a teacher, video, leaflets and questionnaire (Mwidunda *et al.*, 2015), the outcome of the study showed over 10% knowledge uptake regarding *T. solium* related diseases and their transmission dynamics. Other studies that demonstrated that health education on *T. solium* could be a feasible alternative to control of *T. solium* infections were conducted in Mexico, whereby the prevalence of PCC (based on Ab-ELISA) was reduced from 5.2% to 1.2% and HCC (based on Ag-ELISA) from

0.78% to 0.51% a year after the intervention (Sarti *et al.*, 1997). Health education is the cornerstone of health promotion and has been defined as the lifelong process by which individuals acquire knowledge, attitudes and behaviour that promote health and improve the quality of life in venerable communities (Carter *et al.,* 1997; Braae *et al.,* 2016; Bisallah *et al.,* 2018). Furthermore, health educational intervention is highly encouraged because it might lead to permanent changes towards controlling and eventually eliminating the infections. Based on a study performed in the Mbulu, Mpwapwa and Mbinga Districts in Tanzania where knowledge regarding TSTC transmission and prevention was low, researchers identified certain key messages from the community (Nyangi *et al.,* 2022) leading to the development of a community-based health education intervention package for preventing TSTC transmission.

This study hypothesized that imparting specific community based health education to the community regarding human TSTC transmission and prevention would increase their knowledge, improve their preventive practices against the infections and eventually reduce incidences of HCC in endemic areas. Therefore, the study was designed to evaluate the effectiveness of a locally developed community based health education trial against human TSTC in villages of the Kongwa and Songwe Districts representing endemic areas of Tanzania.

1.12 Objectives

1.12.1 Overall objective

The overall objective of this study was to evaluate effectiveness of a developed community based health education intervention for controlling human TSTC in Kongwa and Songwe Districts of Tanzania.

1.12.2 Specific Objectives

i. To assess community baseline knowledge and preventive practices related to transmission, prevention and control of human TSTC in Kongwa and Songwe Districts.
ii. To determine the baseline seroprevalence of HCC and associated factors in Kongwa and Songwe Districts.

iii. To evaluate the effectiveness of community based health education intervention for increasing knowledge, improving practices related to human TSTC and reducing incidences of HCC in Kongwa and Songwe Districts.

1.13 Organization of the Thesis

This thesis is organized into five chapters preceded by an extended abstract summarizing the objectives, materials and methods, key research findings and conclusions of the study. Chapter one covers an introduction, literature review, problem statement and justification of the study and study objectives. Chapters two, three and four are presenting the results generated from the specific objectives which are synthesized into either published papers or manuscripts submitted for publication in peer-reviewed scientific journals. The format and writing style of each paper followed the requirements of the respective journals. Chapter five consists of the overall conclusions and recommendations of the study.

CHAPTER TWO

Paper I

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Paper published in:
Tanzania Veterinary Journal

Need of public health education intervention for better knowledge and practices against human Taenia solium taeniasis/cysticercosis

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Article timeline

Submitted: 04-06-2022, Revised: 15-10-2022, Accepted: 14-06-2023, Published: 20-08-2023

Tanzania Veterinary Journal Vol. 367(1) 2022 ***https://dx.doi.org/10.4314/tvj.v37i1.2***

Need of public health education intervention for better knowledge and practices against human Taenia solium taeniasis/cysticercosis

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SUMMARY

Taenia solium taeniasis/cysticercosis (TSTC) is reported to be endemic in pig producing areas around the world and cause significant public health burden and economic losses. In Tanzania, the parasite has been reported in many pig-raising areas calling for sustainable and cost-effective control approaches Poor knowledge,insufficient hygienic practices, and free range pig management are known to contribute in transmission of the parasite. Intervention in these factors can have a significant impact on the preventing transmission. This survey was conducted to assess the community knowledge and practices associated with human TSTC in Kongwa and Songwe Districts. A structured questionnaire was administered to 872 participants from 42 villages in the districts. The findings indicated that, community knowledge of human TSTC was limited in the study area, whereby a total of 539 (61.8%) participants had low knowledge. Regarding practices, the findings indicated that, a total of 653 (74.9%) participants had low level of practices related to human TSTC transmission. A total of 572 (65.6%) partcipants had low level of knowledge and preventive practices related to human TSTC. However Participants from Kongwa District and those with atleast primary level of education were likely to have higher level of knowledge and preventive practices. The study reveals a significant knowledge gap and adverse practices among participants hindering the effforts of controlling *T. solium* transmision. Since, the parasite poses a significant public health concern, the study suggests designing and implementation of public health education to a broad audience for effective public impact.

Keywords: *Taenia solium*, human, crossectional study, control, Tanzania

INTRODUCTION

Human *Taenia solium* Taeniosis/ Cysticercosis (TSTC) is an emerging public health problem of global concern (WHO, 2016). In Tanzania, the parasite has been reported in many rural pig-raising areas and also urban areas calling for sustainable and cost-effective control approaches (Trevisan *et al.,* 2017). Pigs and humans contract cysticercosis by ingestion of eggs shed in the faeces of *T. solium* human carriers (Johansen *et al.,* 2017). Humans also harbor the final (adult) stage of the parasite in the intestines, a condition called taeniasis acquired through consuming raw or partially cooked cystic pork (Garcia *et al.,* 2007). The impact of the parasite on the community is considerably huge in terms of financial losses, morbidities and mortalities, especially in endemic countries (Torgerson *et al.,* 2018). Human Cysticercosis (HCC) becomes more serious and usually fatal when the manifestation involves the central nervous system (CNS), a condition termed neurocysticercosis (NCC) (Flisser *et al.,* 2003; White, 2000; Winkler, 2012). NCC has been described as the most frequently reported helmintic infection of the CNS and is a major cause of acquired epilepsy in cysticercosis endemic regions (Engels *et al.,* 2003; Garcia *et al.,* 2007).

Taenia solium has a global distribution and is endemic in most parts of sub-Saharan African countries, South and Central America and parts of India (Winkler *et al.,* 2009; Kay, Prüss and Corvalán, 2000). The parasite is infrequently reported in most of Europe (Overbosch *et al.,* 2002; WHO and FAO, 2005). In Tanzania, surveys on HCC and porcine cysticercosis (PCC) have provided evidence that the parasite is spread in many regions of the country (Ngowi *et al.,* 2004; Winkler *et al.,* 2009; Mwang'onde *et al.,* 2012; Komba *et al.,* 2013; Mwanjali *et al.,* 2013; Trevisan *et al.,* 2017; Maganira *et al.,* 2019).

Poor knowledge, insufficient hygienic practices, and free range pig management are known to contribute in transmission of human TSTC (WHO and FAO, 2005). Intervention in these factors can have a significant impact on the preventing parasite transmission in endemic areas.

Studies on knowledge, attitude and practices have shown that knowledge and practices have influence on prevention of human *T.solium* transmission (Elisante *et al.,* 2009; Maridadi *et al.,* 2011). However, limited studies studies are available which describe the influence of knowledge and practices on parasite transmission in endemic areas (Komba, 2008; Maganira *et al.,* 2019; Mwanjali *et al.,* 2013).

Therefore, this study was carried out to determine the knowledge and preventive practices of the community related to human TSTC transmission and management, and their association with socio-demographic characteristics in central and southern zone of Tanzania represented by Kongwa and Songwe Districts respectively. The generated information could help in tailoring appropriate interventions and establish a baseline that could be used to evaluate the effectiveness of future interventions.

MATERIALS AND METHODS

Study area

The survey was conducted from June to September 2019 in Kongwa and Songwe Districts. Kongwa is among the seven Districts of Dodoma region. The District occupies an area of 4,041 square kilometres (NBS, 2012) and it has 22 wards and 92 villages (Mkonda and He, 2017). The human population was 365,952 made up of 61,914 households (NBS, 2016). The key economic activities of the district include agriculture, livestock keeping and other informal sectors. Songwe is among the four Districts of Songwe region. The District is located in south west highlands of Tanzania and has an area of 16,070 square kilometres. The district has 18 wards and 43 villages. The District has a total population of 157,089 composed of 28,282 households. The main economic activities include; farming, livestock keeping, agribusiness, mining and fishing (NBS, 2012). The two Districts were selected purposively based on pig population density, confirmed cases of TSTC and proximity to urban centers (Eom *et al.,* 2011; Komba, 2008; Maganira *et al.,* 2018; Mwanjali *et al.,* 2013).

Study design and data collection:

This was a cross-sectional study and was conducted in accordance with Sokoine University of Agriculture institutional guidelines. The study obtained approval of the National Institute for Medical Research (NIMR) (NIMR/HQ/R.8a/Vol.1X/2802). Permission to conduct the study in the selected villages was obtained from Regional, District and local authorities. Consent for the participation of the selected participants in a household was obtained from the selected individuals as well as the head of the household.

The sample size was calculated using the formula $n=Z^2P(1-P)/d^2$ (Daniel and Cross, 1987.), in which n =required sample size, Z is a *Z* statistic value of 1.96 at the confidence level of 95%, *P* =16%, the estimated prevalence of the infection on the human side nearby the study area (Mwanjali *et al.,* 2013), and d = 0.05, relative precision. Thus, $n = 1.96^2 \times 0.16 \times (1\text{-}0.16)/0.05^2 = 206$ households (one person per household). This number was more than doubled to adjust for the multi-stage sampling design effect, thus, $n_{\text{adjusted}} = 872$. Participating households were randomly selected from 42 villages, 28 from Kongwa (n=87) and 18 from Songwe (n=43) Districts.

To facilitate collection of adequate and correct information, sensitization and mobilization meetings involving researchers and community leaders were conducted, in which the study objectives were explained. Then, a list of all village households accepted to participate was obtained and the list was entered in Microsoft Excel for randomization, using a specific formular. Then, the research team including enumerators visited the selected households and with support from the household head, an eligible household member was identified to participate in the study. The criteria for eligibility were being a permanent household member and being aged between 15–60 years. The study recruited an equal number of households (20 households) per village for all 42 villages.

A Kobo Collect, an open-source Android application for collecting survey data (Kobo Collect v.1.27.3-3) was downloaded from Google Play Store and installed on Android tablets, and the application was used by enumerators for data collection. Data from the households were collected through face-to-face interviews with household heads or representatives. The pre-tested questionnaire included both closed and open-ended questions examining and exploring information on demographic characteristics, knowledge of human TSTC transmission, symptoms, preventive measures, treatment options and sanitary and hygienic practices. Responses on questionnaires were complemented by the direct observation method at the household level.

Data management and analysis:

The collected quantitative data were checked to ensure that the contained information was correct, then imported from the KoBoCollect toolbox into Microsoft Excel and coded before being exported into IBM Statistical Package for Social Sciences SPSS version 20 software for analysis. Univariate analysis was carried out to generate frequencies. The knowledge of respondents was measured using the scoring method from a previous study (Bati *et al.,* 2013; Dohoo *et al.,* 2009), each correct response was scored one and for "incorrect" and "don't know" responses the score was zero. Briefly, weights of 0-10 points were subjectively assigned as overall scores to the responses on questions assessing each knowledge/practice variable.

A respondent was considered to have high level of knowledge/safety practice, or low level of knowledge/ safety practice on a particular variable when his/her total responses scores were 6-10 points and 0-5 points, respectively. Furthermore, each respondent was assigned to a total scoring for combined responses of both general knowledge and safe practices variables. The score performance ranged from 0 to 20 as there were a total of 20 variables, whereby scores of 1-10 points and 11-20 points were considered as low level and high level of knowledge and preventive practices, respectively. The binary logistic regression model was used to test for associations between categorical variables. Knowledge and preventive practice scores were compared with selected social demographic factors using non-parametric tests (Mann–Whitney U test and Kruskal–Wallis test). The significance level was $p < 0.05$.

RESULTS

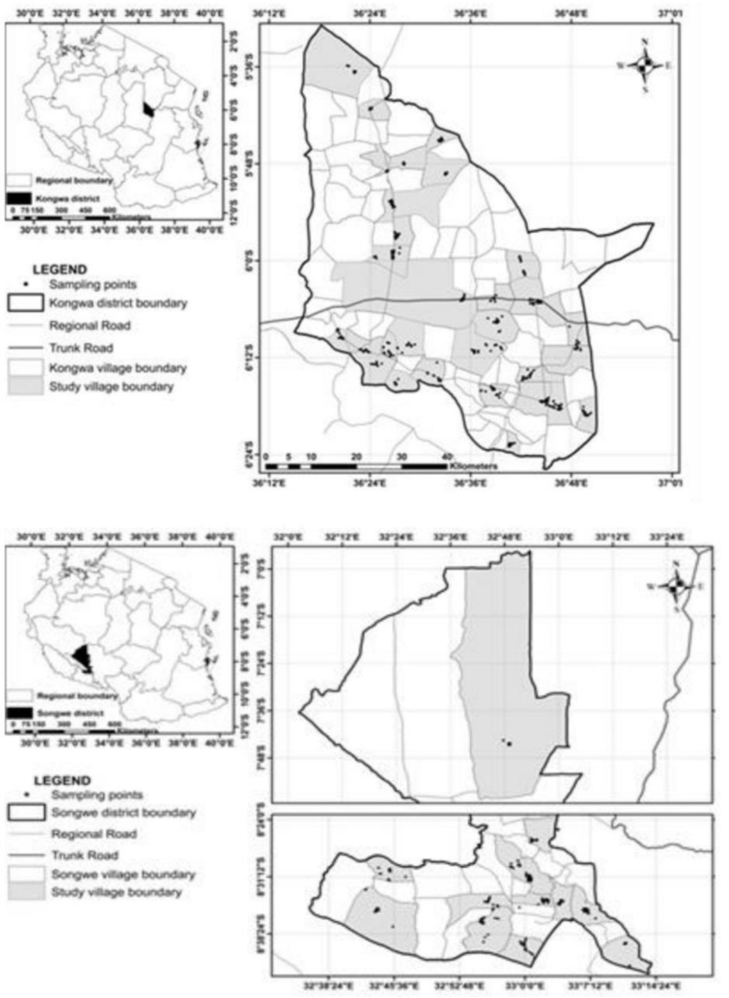

Figure 1. **A**. Map of Tanzania (top left) showing the location of Kongwa District (shaded black) and the enlarged map (right). **B** Map of Tanzania (bottom left) showing the location of Songwe District (shaded black) and two enlarged maps (bottom right). The black dots in enalarged maps of both Districts indicate the distribution of participating households (sampling points). Total of 593 households were sampled in Kongwa District (Figure 1A) and 279 households in Songwe District (Figure 1B) respectively

Table 1: Association between location, sex, age and education level on overall knowledge of human *T. solium* taeniosis/cysticercosis

	Level of knowledge		Odds Ratios (OR)	
	Low n (%)	High n (%)	Crude OR	Adjusted OR (AOR)
District				
Kongwa	331(55.8)	262(44.2)	2.14(1.693,3.176)*	2.49(1.780,3.470)*
Songwe	208(74.6)	71(25.4)	1	1
Total	539(61.8)	333(38.2)		
Sex				
Male	367(62.5)	220(37.5)	0.91(0.683,1.220)	0.93(0.675,1.280)
Female	172(60.4)	113(39.6)	1	1
Total	539(61.8)	333(38.2)		
Age(Years)				
15-25	45(62.5)	27(37.3)	0.97(0.575,1.637)	0.68(0.383,1.212)
26-45	274(61.7)	170(38.3)	1.01(0.753,1.337)	0.83(0.611,1.139)
>45	220(61.8)	136(38.2)	1	1
Total	539(61.8)	333(38.2)		
Educational level				
Primary	383(61.4)	241(38.6)	2.78(1.794,4.330)*	2.93(1.865,4.589)*
Secondary	31(40.3)	46(59.7)	6.57(3.560,12.129)*	7.92(4.174,15.018)*
Tertiary	1(5.3)	18(94.7)	79.71(10.21,622.32)*	92.67(11.69,734.18)*
Informal	124(81.6)	28(18.4)	1	1
Total	539(61.8)	333(38.2)		

There is association between location and education level on the level of knowledge related to TSTC.
OR= Odds ration or Crudes Odds ratio ;a measure of association between an exposure and an outcome;
AOR = Adjusted odds ratio; a measure of association used to control confounding bias.
*Significant factor at 95%CI (n=872)

Association of location, age, sex and education level of participants with knowledge regarding human *T.solium* taeniosis/cysticercosis

A total of 872 participants were involved in the study, whereby the proportion of 593 (68%) and 279(32%) participants were from the villages of Kongwa and Songwe Districts, respectively. The majority of participants 587(67.3%) were males. The age of all participants ranged from 15-60 years and about half 444 (50.9%) of all participants were adults aged between 26-45 years. Most of the participants 624 (71.6%) had a primary level of education (Supporting Table 1). Among the participants, 539 (61.8%) were found to have low level of knowledge based on selected knowledge variables. Also a proportion of 208(74.6%) participants from Songwe District had low level of knowledge. Interestingly, the majority 124 (81.6%) of participants with informal education had low level of knowledge with respect to human TTSC. Participants from Kongwa Districts and those with primary, secondary and tertiary levels of education were likely to have higher level of knowledge than participants from Songwe District and participants with informal level of education respectively (Table 1)

Association between location, sex, age and education level of participants on preventive practices regarding human *T.solium* taeniosis/cysticercosis

For the general preventive practices variables, findings presented in Table.2 shows that, total of 653(74.9%) participants had lower level of preventive practices regarding transmission and control of human TSTC. Also, further findings showed that, 241(86.4) participants from Songwe District had low level of preventive practices. Also, the majority 136 (89.5%) of participants with informal level of education had low level preventive practices. Participants from Kongwa Districts and those with primary, secondary and tertiary levels of education were likely to have higher level of preventive practices than participants from Songwe District and participants with informal level of education respectively

Table. 2: Association between location, sex, age and education level of participants on overall preventive practices against human *T. solium* taeniasis/cysticercosis (N=872)

	Level of Practices		Odds Ratios (OR)	
	Low n (%)	High n (%)	Crude OR	Adjusted OR
District				
Kongwa	412(69.5)	181(30.5)	2.139(1.693,3.176)*	2.49(1.780,3.470)*
Songwe	241(86.4)	38(13.6)	1	1
Total	653(74.9)	219(25.1)		
Sex				
Male	435(74.1)	152(25.9)	0.912(0.683,1.220)	0.93(0.675,1.280)
Female	218(76.5)	67(23.5)	1	1
Total	653(74.9)	219(25.1)		
Age (Years)				
15-25	53(73.6)	19(26.4)	0.971(0.575,1.637)	0.68(0.383,1.212)
26-45	338(76.1)	106(23.9)	1.004(0.753,1.337)	0.83(0.611,1.139)
>45	262(73.6)	94(26.4)	1	1
Total	653(74.9)	219(25.1)		
Educational level				
Primary	470(75.3)	154(24.7)	2.787(1.794,4.330)*	2.93(1.865,4.589)*
Secondary	45(58.4)	32(41.6)	6.571(3.560,12.129)*	7.92(4.174,15.018)*
Tertiary	2(10.5)	17(89.5)	79.714(10.211,622.32)*	92.67(11.697,734.183)*
Informal	136(89.5)	16(10.5)	1	1
Total	653(74.9)	219(25.1)		

There is association between location and education level on the level of practices related to TSTC.
OR= Odds ration and Crudes Odds ratio ;a measure of association between an exposure and an outcome;
AOR = Adjusted odds ratio; a measure of association used to control confounding bias
*Significant factor at 95%CI.

Association of location, sex, age and education level of participants on knowledge and practices regarding human *T. solium* taeniosis/ cysticercosis

Table.3 shows results for the combined responses, whereby a total of 572(65.6%) respondents had lower level of knowledge and preventive practices regarding human TSTC. The majority 215(77.1%) of participants from Songwe had low level of knowledge and preventive practices whereas 130(85.5%) respondents with informal level of education had low level of knowledge and preventive practices related to human TSTC. Participants from Kongwa Districts and those with primary, secondary and tertiary levels of education were likely to have higher level of preventive practices.than participants from Songwe District and participants with informal level of education respectively.

Table 3: Association between location, sex, age and education level of participants on overall knowledge and practices against human *T. solium* taeniosis/cysticercosis (N=872)

	Level of knowledge and practices		Odds Ratios	
	Low n(%)	High n(%)	COR	AOR
District				
Kongwa	357(60.2)	236(39.8)	2.221(1.606,3.070)*	2.379(1.690,3.348)*
Songwe	215(77.1)	64(22.9)	1	1
Total	572(65.6)	300(34.4)		
Sex				
Male	387(65.9)	200(34.1)	0.956(0.710,1.287)	0.940(0.679,1.303)
Female	185(64.9)	100(35.1)	1	1
Total	572(65.6)	300(34.4)		
Age(Years)				
15-25	51(70.8)	21(29.2)	0.752(0.433,1.306)	0.515(0.280,0.946)
26-45	291(65.5)	153(34.5)	0.960(0.716,1.286)	0.799(0.582,1.098)
>45	230(64.6)	126(35.4)	1	1
Total	572(65.6)	300(34.4)		
Educational level				
Primary	404(64.7)	220(35.3)	3.218(1.990,5.204)*	3.358(2.058,5.479)*
Secondary	35(45.5)	42(54.5)	7.091(3.751,13.403)*	8.843(4.548,17.192)*
Tertiary	3(15.8)	16(84.2)	31.515(8.475,117.186)*	36.622(9.650,138.977)*
Informal	130(85.5)	22(14.5)	1	1
Total	572(65.6)	300(34.4)		

There is association between location and education level on the level of overall knowledge and practices related to TSTC. OR= Odds ration or Crudes Odds ratio ;a measure of association between an exposure and an outcome; AOR = Adjusted odds ratio; a measure of association used to control confounding bias *Significant factor at 95%CI.

DISCUSSION

Effective and sustainable prevention of any infectious disease requires an assessment not only of the prevalence of an infection in the community but also their knowledge, attitudes and practices regarding the disease (Maridadi *et al.,* 2011; Trevisan *et al.,* 2017) and how they influence prevention of TSTC. The study investigated community knowledge and practices on TSTC prevention and how they are influenced by location, sex, education and age in the selected villages of Kongwa and Songwe Districts as case studies. The participants in the study included those without primary education 152(17.4%), primary eduction 624(71.6%), secondary education 77(8.8%) and tertiary level 19(2.2%) (Supporting Table 1). The findings of the study revealed that community knowledge was generally low and there were poor preventive practices against human TSTC in the studied Districts. Similar observations were made in other community-based studies carried out in Kilolo District, found in southern highlands of Tanzania, where participants had low knowledge about TSTC including failure to link taeniosis, HCC and PCC (Elisante, 2009; Maridadi *et al.,* 2011; Mwanjali *et al.,* 2013; Mwang'onde *et al.,* 2014).

However, there was differences between Districts on the knowledge and preventive practices (AOR=2.379, 95% CI, (1.690, 3.348), $p < 0.001$) (Table 3), where participants with primary education and above were likely to have better knowledge and preventive practices in Kongwa than participants from Songwe District. The geographical location were found to be significantly associated with the level of knowledge and preventive practices regarding the transmission and management of human TSTC. The cause of this difference is not known. Nonetheless the difference could be attributable to the fact that Kongwa District is close to Dodoma capital city of the country where the possibility of accessing public health education is higher compared to Songwe District which is located relatively in remote location. Furthermore, Songwe District is a new district established in 2012 with relatively limited access to safe and sufficient clean water to facilitate hygienic practices (Thomas *et al.,* 2011; NBS, 2012; NBSAS, 2015) to facilitate prevention of TSTC that is a common cause of NCC.

It should be noted that, neurocysticercosis is an important cause of acquired epilepsy in humans in endemic countries, however, in this study, most participants were not able to associate epilepsy with the parasite but rather with witchcraft or evil. This was not surprising in areas with low knowledge as other studies in similar settings reported more or less similar findings (Winkler *et al.,* 2009; Pandian *et al.*, 2011; Mwang'onde *et al.,* 2014; Sankhyan *et al.,* 2015; Kungu *et al.,* 2017). The limited community knowledge of TSTC was also noted in other countries where TSTC is endemic (Kisinza *et al.,* 2008; Mutua *et al.,* 2010; Sankhyan *et al.,* 2015; Kungu *et al.,* 2017; Millogo *et al.,* 2019). This may be related to the fact that specific knowledge related to the transmission of TSTC was lacking in the general community as it was reported in Delhi and Mexico (Sarti *et al.,* 1997 and Alexander *et al.,* 2012).

The adoption of preventive practices is highly influenced by knowledge of the transmission cycle of the TSTC (Ngowi *et al.,* 2008). Also, the use of safe and clean water, hand washing with soap and latrine use are considered by WHO as the key hygiene behaviours that limit the burden of infectious diseases including TSTC (Thomas *et al.,* 2013; WHO, 2021). In this study, the assessment of preventive practices found a low number of respondents drinking treated water (Supporting Table 2). This could probably be due to the limited supply of safe and clean water as well as the lack of specific knowledge related to water safety as observed in most of the study villages and other studies elsewhere in Tanzania (Thomas *et al.,* 2013; World Health Organization, 2015). Where there was no reliable water sources people are likely to use any available sources which are likely to increase the risk of exposure to contaminated water with *T. solium* eggs from human carriers especially where open-door defecation is common (Sarti and Rajshekhar. 2003; García *et al.,* 2007; Ngowi *et al.,* 2007; Alexander *et al.,* 2012).

Indeed, the open door defecation coupled with pig rearing practices where pigs are freely roming was a common practice in the study areas (supporting Table 2). Furthermore, the study observed some community centers in study villages (local bars and markets) lacking toilets which may encourage open defecation practices, resulting in environmental contamination with *T. solium* eggs. Nevertheless, it was encouraging to observe greater availability of toilets in schools than in individual homes. Having functional toilets in schools may thus be a positive initial step in increasing the utilization of toilets among members in the community.

Toilets/ latrine use has in recent years been highly promoted in most of the districts in Tanzania through health promotion program coordinated by the Ministry of Health. The program is estimated to increase the overall access to basic latrine up to an average of 93% countrywide (Thomas *et al.,* 2013) suggesting that, public health eduction through campaigns is one of the effective tools of positive changes in the community. Unfortunately, the programme did not cover some parts of the country including the studied Districts based on information colleted from the respective District health authorities of Kongwa and Songwe respectively.

Furthermore, the study indicated that not all participants practice hand washing with soap after attending the toilets, meaning that other people would possibly remain with contaminated hands, hence increasing the chance of parasitic infection transmission. This may further increase the risk of transmission of TSTC as shown in previous studies where the prevalence of parasitic infections and infestations in Tanzania is related to poor hand-washing behavior (Ngowi *et al.,* 2004; Mwang'onde *et al,* 2014; Thomas *et al.,* 2013; Kabululu *et al.,* 2015). The unsafe practices observed in this study were also noted by other studies in Southern and Nothern Tanzania where *T. solium* infection is endemic (Maridadi *et al.,* 2011; Mwang'onde *et al.,* 2014; Mwanjali *et al.,* 2013; Ngowi *et al.,* 2004). This signifies the fact that education intervention of human TSTC and its management is needed to minimize the knowledge gap and adverse practices (Elisante, 2009; Maridadi *et al.,* 2011; Mwang'onde *et al.,* 2014; Ngowi *et al.,* 2008, 2004).

The study reveals that, there is a significant knowledge gap and adverse practices regarding human TSTC transmission and management, leading to misconceptions and ineffective control measures in all areas not covered by publich health intereventions. Having primary education or higher is not sufficient to have knowledge and better practices on prevention of transmission of TSTC. Lesson learned from National health promotion programs coordinated by the Ministry of Health where the average access to basic latrine reached 93% countrywide suggest that the implementation of public health education could have more impact and should be designed to reach a broad audience, including school children, community leaders, and the general population.

ACKNOWLEDGEMENT

This research was funded by the German Federal Ministry of Education and Research (BMBF) and facilitated by the CYSTINET-Africa consortium under CYTINET-Africa SUA project number 81203596 and CYSTINET-Africa TUM I project number 01KA1618. The funder had no role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

CONFLICTS OF INTEREST

The authors declare no competing interests.

REFERENCES

Alexander, A.M., Mohan, V.R., Muliyil, J., Dorny, P., Rajshekhar, V. Changes in knowledge and practices related to taeniasis/cysticercosis after health education in a south Indian community. *Int. Health* 4, 164–169, 2012.

Bati, J., Legesse, M., Medhin, G. Community's knowledge, attitudes and practices about tuberculosis in Itang Special District, Gambella Region, South Western Ethiopia. *BMC Public Health* 13, 734, 2013.

Daniel, W.W., Cross, C.L., n.d. Biostatistics: A Foundation for Analysis in the Health Sciences *John Wiley & Sons, Inc. 111 River Street*, 2013.

Dodoma Region Report. Retrieved on 20th July 2018 from http://www.fao.org/tempref/AG/Reserved/PPLPF/ftpOUT/GLiPHA/DATA/Queue/Working/tanzania/DODOMA%20REGION%20REPORT. 2003.

Dohoo, I.R., Martin, S.W., Stryhn, H. Veterinary epidemiologic research. *VER, Inc., Charlottetown*, 2009.

Elisante, R. Lay people's knowledge, perceptions and practices regarding the transmission and management of human and porcine cysticercosis in Mbeya rural District of Tanzania. *University of Nairobi, Kenya*, 2009.

Engels, D., Urbani, C., Belotto, A., Meslin, F., Savioli, L. The control of human (neuro) cysticercosis: which way forward? *Acta Trop.* 87, 177–182, 2003.

Eom, K.S., Chai, J.-Y., Yong, T.-S., Min, D.-Y., Rim, H.-J., Kihamia, C., Jeon, H.-K. Morphologic and Genetic Identification of *Taenia* Tapeworms in Tanzania and DNA Genotyping of *Taenia solium*. *Korean J. Parasitol.* 49-399, 2011.

Fabiani, S., Bruschi, F. Neurocysticercosis in Europe: Still a public health concern not only for imported cases. *Acta Trop*. 128, 18–26, 2013.

Flisser, A., Sarti, E., Lightowlers, M., Schantz, P. Neurocysticercosis: regional status, epidemiology, impact and control measures in the Americas. *Acta Trop. 87, 43–51*, 2003.

García, H.H., González, A.E., Del Brutto, O.H., Tsang, V.C.W., Llanos-Zavalaga, F., Gonzalvez, G., Romero, J., Gilman, R.H. Strategies for the elimination of taeniasis/cysticercosis. *J. Neurol. Sci. 262,* 153–157, 2007.

Garcia, H.H., Tsang, V.C.W., Gilman, R.H. New concepts in the diagnosis and management of neurocysticercosis. *American. Soc. Trop. Med*. 72, 3-9, 2005.

Mwang'onde, B., Nkwengulila, G., Chacha, M., 2012. The Serological Survey for Human Cysticercosis Prevalence in Mbulu District, Tanzania. *Adv. Infect. Dis.* 02, 62–66, 2012.

Johansen, M.V., Trevisan, C., Gabriël, S., Magnussen, P., Braae, U.C. Are we ready for *Taenia solium* cysticercosis elimination in sub-Saharan Africa? *Parasitol.* 144, 59–64, 2017.

Kabululu, M.L., Ngowi, H.A., Kimera, S.I., Lekule, F.P., Kimbi, E.C., Johansen, M.V. Risk factors for prevalence of pig parasitoses in Mbeya Region, Tanzania. *Vet. Parasitol.* 212.

Kay, D., Prüss, A., Corvalán, C. Methodology for assessment of Environmental burden of disease. WHO, 2000.

Kisinza, W., Talbert, A., Mutalemwa, P., McCall, P. Community knowledge, attitudes and practices related to tick-borne relapsing fever in Dodoma Rural District, Central Tanzania. Tanzan. *J. Health Res.* 10, 131–136, 2008.

Komba, E.V.G., 2008. Prevalence of porcine cysticercosis in Mbozi and Mbeya rural districts, Mbeya Tanzania (Thesis). *Sokoine University of Agriculture*, 2008.

Komba, E.V.G., Kimbi, E.C., Ngowi, H.A., Kimera, S.I., Mlangwa, J.E., Lekule, F.P., Sikasunge, C.S., Willingham, A.L., Johansen, M.V., Thamsborg, S.M., 2013. Prevalence of porcine cysticercosis and associated risk factors in smallholder pig production systems in Mbeya region, southern highlands of Tanzania. *Vet. Parasitol.* 198, 284–291, 2013.

Kungu, J.M., Dione, M.M., Ejobi, F., Ocaido, M., Grace, D. Risk factors, perceptions and practices associated with Taenia solium cysticercosis and its control in the smallholder pig production systems in Uganda: a cross-sectional survey. *BMC Infect. Dis.* 17, 1, 2017.

Maganira, J.D., Hepelwa, N.I., Mwang'onde, B.J., 2018. Seroprevalence of Porcine Cysticercosis in Ludewa District, Njombe, Tanzania. *Adv. Infect. Dis*. 08, 151, 2018.

Maganira, J.D., Mwang'onde, B.J., Kidima, W., Mwita, C.J., Höglund, J. Seroprevalence of circulating taeniid antigens in pigs and associated risk factors in Kongwa district, Tanzania.

*Parasite Epidemiol. Contro*l 7, e00123, 2019.

Maridadi, A.F., Lwelamira, J., Simime, F.G. Knowledge and Practices Related to T. solium Cysticercosis -Taeniasis among Smallholder Farmers in Selected Villages in Kilolo District in Iringa Region in Southern Highlands of Tanzania. *J Anim Vet Adv* 3(3): 196-201, 2011.

Mbozi District Socio-Economic Profile. Retrieved on 12th July 2020 from http://www.tzonline.org/pdf/ Mboziprf, 2005.

Millogo, A., Ngowi, A.H., Carabin, H., Ganaba, R., Da, A., Preux, P.-M. Knowledge, attitudes, and practices related to epilepsy in rural Burkina Faso. *Epilepsy Behav.* 95, 70–74, 2019.

Mkonda, M., He, X. Are Rainfall and Temperature Really Changing? Farmer's Perceptions, Meteorological Data, and Policy Implications in the Tanzanian Semi-Arid Zone. *Sustainab.* 9, 1412, 2017.

Mutua, F., Arimi, S., Ogara, W., Dewey, C., Schelling, E. Farmer Perceptions on Indigenous Pig Farming in Kakamega District, Western Kenya. *Nordic Journal of African Studies* 19(1): 43–57, 2010.

Mwang'onde, B.J., Nkwengulila, G., Chacha, M., 2014. The risk factors for human cysticercosis in Mbulu District, Tanzania. *Onderstepoort J Vet Res* 81, 2014.

Mwanjali, G., Kihamia, C., Kakoko, D.V.C., Lekule, F., Ngowi, H., Johansen, M.V., Thamsborg, S.M., Willingham, A.L. Prevalence and Risk Factors Associated with Human Taenia Solium Infections in Mbozi District, Mbeya Region, Tanzania. *PLoS Negl. Trop. Dis.* 7, e2102, 2013.

Mwidunda, S.A., Carabin, H., Matuja, W.B.M., Winkler, A.S., Ngowi, H.A., 2015. A school based cluster randomised health education intervention trial for improving knowledge and attitudes related to Taenia solium cysticercosis and taeniasis in Mbulu district, northern Tanzania. *PloS One* 10, e0118541, 2015.

National Bureau of Statistics. Regional Profiles. Retrieved on 10th May 2021 from https://www.nbs.go.tz/index.php/en/regional-profiles, 2012 .

National Bureau of Statistics - Agriculture Statistics. Retrieved on 28th July 2021 from https://www.nbs.go.tz/index.php/en/census-surveys/agriculture-statistics, 2016.

Ngowi, H.A., Carabin, H., Kassuku, A.A., Mlozi, M.R.S., Mlangwa, J.E.D., Willingham, A.L. A health-education intervention trial to reduce porcine cysticercosis in Mbulu District, Tanzania. *Prev. Vet. Med.* 85, 52–67, 2008.

Ngowi, H.A., Kassuku, A.A., Maeda, G.E.M., Boa, M.E., Carabin, H., Willingham, A.L. Risk factors for the prevalence of porcine cysticercosis in Mbulu District, Tanzania. *Vet. Parasitol.* 120, 275–283, 2004.

Ngowi, H.A., Tolma, E.L., Kassuku, A.A., Mlozi, M.R.S., Mlangwa, J.E.D., Carabin, H., Willingham, A.L., 2007. Using the PRECEDE model to plan a health promotion strategy for control of *Taenia solium* infections in northern Tanzania. *Int. J. Health Promot. Educ.* 45, 41–48, 2007.

Pandian, J., Girotra, M., Gera, C., Abraham, R., Gauba, R., Bansal, T., Kaur, P., Singh, Y., 2011. Awareness of neurocysticercosis: A study from Northwest India. Ann. *Indian Acad. Neurol*. 14, 27, 2011.

Sankhyan, P., Gupta, S., Singh, G. Knowledge about, attitudes towards, practices regarding Taenia solium cysticercosis among people attending an epilepsy clinic in India. *Int. J. Epilepsy* 02, 6–010, 2015.

Sarti, E., Flisser, A., Schantz, P.M., Gleizer, M., Loya, M., Plancarte, A., Avila, G., Allan, J., Craig, P., Bronfman, M., Wijeyaratne, P. Development and evaluation of a health education intervention against Taenia solium in a rural community in Mexico. *Am. J. Trop. Med. Hyg*. 56, 127–132, 1997.

Sarti, E., Rajshekhar, V. Measures for the prevention and control of Taenia solium taeniosis and cysticercosis. *Acta Trop*. 87, 137–143, 2003.

Thomas, D.J., Holbro, D.N., Young, M.D. A Review of Sanitation and Hygiene in Tanzania. 86, 2013.

Torgerson, P.R., Rüegg, S., Devleesschauwer, B., Abela-Ridder, B., Havelaar, A.H., Shaw, A.P.M., Rushton, J., Speybroeck, N. zDALY: An adjusted indicator to estimate the burden of zoonotic diseases. *One Health* 5, 40–45, 2018.

Trevisan, C., Devleesschauwer, B., Schmidt, V., Winkler, A.S., Harrison, W., Johansen, M.V., 2017. The societal cost of Taenia solium cysticercosis in Tanzania. *Acta Trop*. 165, 141–154, 2017.

White, A.C. Neurocysticercosis: Updates on Epidemiology, Pathogenesis, Diagnosis, and Management. *Annu. Rev. Med*. 51, 187–206, 2000.

WHO. Preventable epilepsy: *Taenia solium* infection burdens economies, societies and individuals. Retrieved on 9th June 2018 from http://www.who.int/taeniasis/resources/9789241549486/en/, 2016.

WHO. Estimates of the global burden of foodborne diseases. Retrieved on 20th July 2018 from http://www.who.int/en/, 2015.

WHO. Taeniasis/ Cysticercosis. Retrieved on 5th February 2021 from https://www.who.int/news-room/fact-sheets/detail/taeniasis-cysticercosis, 2015.

Winkler, A.S. Neurocysticercosis in sub-Saharan Africa: a review of prevalence, clinical characteristics, diagnosis, and management. *Pathog. Glob. Health* 106, 261–274, 2012.

Winkler, A.S., Blocher, J., Auer, H., Gotwald, T., Matuja, W., Schmutzhard, E. Epilepsy and neurocysticercosis in rural Tanzania—An imaging study. *Epilepsia* 50, 987–993, 2009.

SUPPORING INFORMATION

Supporting Table 1. Social-demographic distribution of participants (N = 872)

Variable	Participants n (%)
District	
Kongwa	593 (68.0)
Songwe	279 (32.0)
Sex	
Male	587 (67.3)
Female	285 (32.7)
Age	
15-25years	72 (8.3)
26-45years	444 (50.9)
>45years	356 (40.8)
Education level	
Informal	152 (17.4)
Primary education	624 (71.6)
Secondary education	77 (8.8)
Post-Secondary	19 (2.2)

Supporting Table 2 Knowledge and preventive practices of participants regarding human *T. solium* taeniasis/cysticercosis (N=872).

Characteristic	Participants' responses n (%)
Knowledge	
Has heard about human TSTC	
No	722(82.8)
Yes	150(17.2)
It is safe to consume PCC infected pork	
No	89(10.2)
Yes	783(89.8)
Human acquires TSTC through fecal contaminated water/food	
No	751(86.1)
Yes	121(13.9)
T. solium infect both human and pigs.	
No	752(86.2)
Yes	120(13.8)
Human TSTC can cause epilepsy/ seizures.	
No	
Yes	772(88.5)
	100(11.5)
Practice	
Pigs roam freely in open fields	
No	15(1.7)
Yes	857(98.3)
Always wash fruits and vegetable before consumption	
No	80(9.2)
Yes	792(90.8)
Always use toilets/latrines at home	
No	355(40.7)
Yes	517(59.3)
Washing hands with soap after defecation	
No	293(33.6)
Yes	579(66.4)
Use official water sources	
No	293(33.6)
Yes	579(66.4)
Always drink treated water	
No	673(77.2
Yes	199(22.8)

CHAPTER THREE

Paper II

Seroprevalence of Human *Taenia solium* cysticercosis and its associated factors in villages of Kongwa and Songwe Districts of Tanzania

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Manuscript under review in:
Parasite Epidemiology and Control journal

Abstract

Background: *Taenia solium* taeniosis/cysticercosis is a serious public health and economic problem in many low and middle income countries. Tanzania is among the sub-Saharan African countries endemic for porcine cysticercosis, which increases the risk of human taeniosis and eventually human cysticercosis. This study was performed to estimate seroprevalence of human *T. solium* cysticercosis and its associated factors in villages of Kongwa and Songwe Districts of Tanzania.

Methods: This was a cross-sectional study carried out between June and September 2019 in 42 villages of Kongwa and Songwe Districts. It involved a total of 872 participants of which 593 and 279 participants were from Kongwa and Songwe Districts respectively. All participants were randomly selected from participating villages. Blood samples were collected from all selected participants and tested for human *T. solium* cysticercosis using Ag-ELISA and Wb-Ab assay.

Structured questionnaires were administered followed by direct observations to the study population to investigate factors associated with parasite transmission. Univariate logistic regression model was used to estimate factors associated with seroprevalence of human cysticercosis.

Results: Of the 872 human sera examined by Ag-ELISA, 12 (1.4%) participants were detected with active *T. solium* cysticercosis. Among the actively infected cases, 7(1.2%) and 5(1.8%) of the detected cases were from Kongwa and Songwe District respectively. Furthermore, the results obtained also indicated considerable variation of *T. solium* cysticercosis seropositivity across various factors, however participants who were 45 year of age and above were more likely to be infected with *T. solium* cysticercosis than other age groups (OR=5.9, 95% C. I. 1.37-5.49, p = 0.001).

Conclusions: Human *T. solium* cysticercosis is still a public health problem in Kongwa and Songwe District. Being above 45 year of age was a significant determinant for the for acquiring the infection. However, more work is required to understand other factors that contribute to transmission dynamics of *T. solium* in endemic rural areas. Therefore, appropriate interventions, including health education to the entire population at risk should be implemented for sustainable control.

Keywords: Human *Taenia solium*; Cysticercosis; seroprevalence; Tanzania

1.0 Introduction

Human cysticercosis (HCC) is a zoonotic disease and infection caused by larval stage (cysticercus) of the parasite *Taenia solium.* The disease and infection has serious public health and economic impact in endemic countries (Praet *et al.* 2010a). The larval stage is also found in pig as intermediate host where it causes porcine cysticercosis (PCC). Human acquire HCC when accidentally ingest eggs of the parasite (Flisser 2006). When cysticerci lodge in the central nervous tissues, this results into a condition referred to as neurocysticercosis (NCC) (Gonzales *et al.* 2016; WHO 2016). Humans also harbour the adult (final) stage of the parasite, a condition called taeniosis (Arriola *et al.* 2014)). *T. solium* cysticercosis represents a substantial burden because of its impact on human health, including NCC, animal health and welfare as well as economic losses due to disability and lost pig productivity (Phiri *et al.,* 2003; Ngowi *et al.,* 2004; Carabin *et al.,* 2006; Trevisan *et al.,* 2017).

In sub-Saharan Africa, the presence of PCC is well established (Mafojane *et al.* 2003; Sikasunge *et al.* 2008), however limited information on HCC/NCC is existing (Winkler, 2012). The prevalence of HCC ranges from 7.4% in South Africa to 20.5% in Mozambique (based on specific antibody detection) and was reported to be 21.6% in the Democratic Republic of Congo (based on circulating antigen detection) (Afonso *et al.,* 2011). A recent meta-analysis on the prevalence of NCC in people with epilepsy in endemic areas, found that NCC was the cause of epilepsy in almost 30% of people with epilepsy (Ndimubanzi *et al.* 2010). Furthermore, NCC has been reported to be the main cause of epilepsy in humans in pig-keeping communities of many low- and middle income countries (Winkler *et al.* 2009; Trevisan *et al.* 2017).

Tanzania is known to be among countries endemic for *T.solium* infections, a situation strongly associated with lack of knowledge about the parasite and its zoonotic potentials, poverty, poor hygiene and sanitation, free-range pig management and lack of meat inspection (Ngowi et al., 2004, 2010; Komba, 2008; Mwanjali et al., 2013; Mwang'onde et al., 2014). Also, lack of or inadequate diagnostic capacity (e.g., serological and neuroimaging tests) for detecting HCC and NCC in Tanzania is a limiting factor for effective management and control of the infections. Moreover, the high cost and limited availability of neuroimaging tests (CT scan or MRI) is prohibitive for the right diagnosis for most people (WHO, 2005; Mwanjali et al., 2013).

In Tanzania, HCC prevalence of 16–17% has been estimated in the general population based on Ag-ELISA or IgG western blot methods (Mwanjali *et al.,* 2013; Mwang'onde *et al.,* 2014). These data emphasize the need for more studies in humans to gather information on the persistence of the parasite and factors associated with its transmission despite various ongoing effort to control it. Narrowing down to specific socio-demographic factors that influence HCC transmission could provide evidence for setting up effective intervention programmes and allocate appropriate resources (Sohrabi *et al.* 2021).

This cross-sectional study was conducted to estimate seroprevalence of HCC and associated predictors before a large village level health education randomized trial in 42 villages of Kongwa and Songwe Districts of Tanzania.

2.0 Materials and Methods

2.1 Study Area

This study was carried out between June and September 2019, in Kongwa and Songwe Districts located in central zone and southern highlands of Tanzania, respectively. The districts were selected based on the fact of free range pig production and confirmed cases of *T. solium* infections in human and pigs (Eom *et al.,* 2011; Mwanjali *et al.,* 2013; Maganira *et al.*, 2019). Kongwa District (**Fig. 1**) occupies an area of 4,041 square kilometres and has 22 wards and 87 villages. The human population was 365,952 made up of 61,914 households (NBS, 2016). The key economic activities of Kongwa District are agriculture, livestock production and other informal sectors. The mean temperature is about 26.5°C and main rain season is from November to April with an average annual rainfall of 500 - 800 mm (NBS, 2012).

Songwe District (**Fig. 2)** had a total population of 157,089 people living in 28,282 households. Inhabitants mainly engage in agriculture, livestock activities, mining, fishing and other informal sectors as sources of income. The district experiences a hot season from early September to late April and a cool season from May to late August. The mean temperature is about 26.5°C. The district has one long rainy season, usually from November to Mid- May, which records between 750 mm and 2000 mm per annum (Songwe-Profile, 2015).

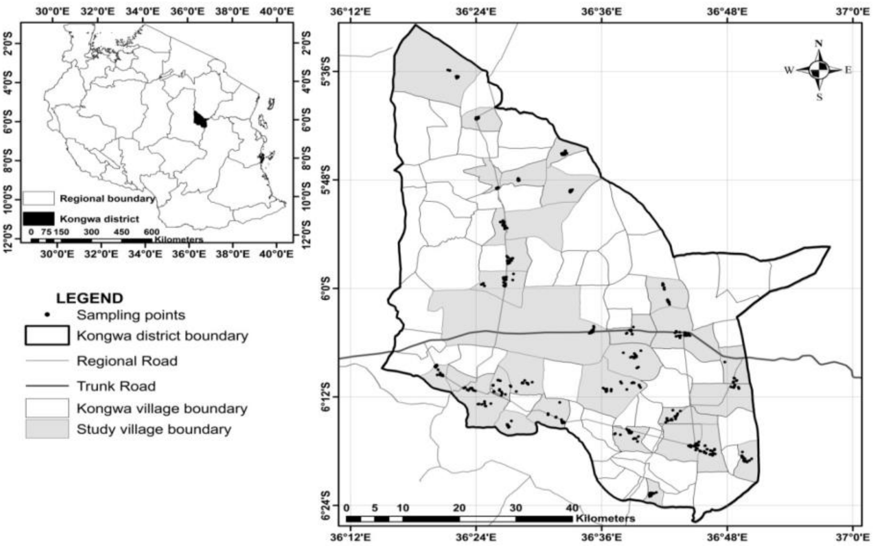

Figure 2.1: Map of Kongwa District showing distribution of the sampled households in study villages to estimate seroprevalence of HCC. The sampling points refer to households.

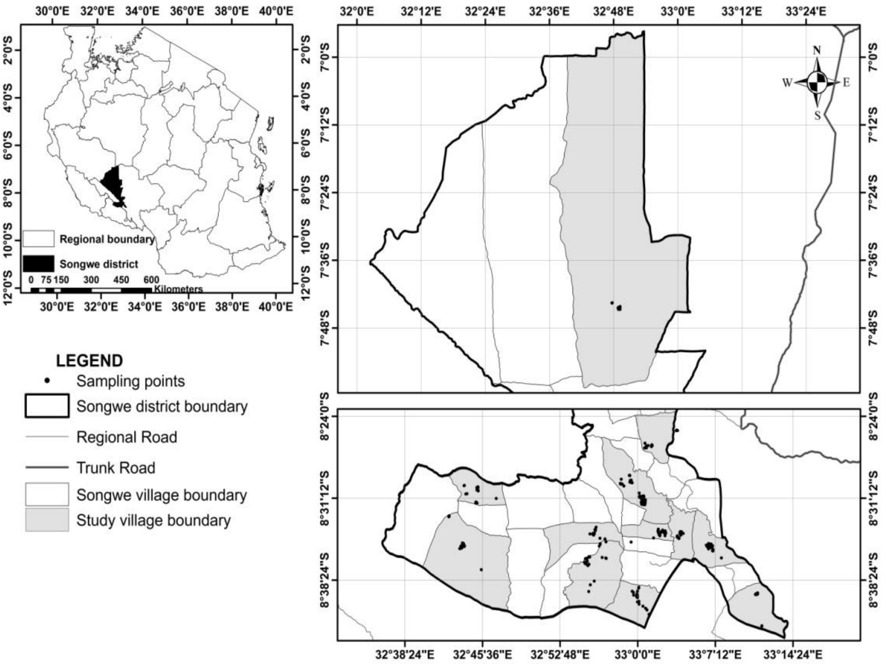

Figure 2. 2: Map of Songwe District showing distribution of the sampled households in study village to estimate seroprevalence of HCC. The sampling points refer to households.

2.2 Study design and sample size estimation

This was a cross-sectional study. Seroprevalence of 16.7% HCC based on Ag-ELISA in the general population in Mbozi District which is nearby Songwe District has been considered in this study (Mwanjali *et al.,* 2013). Sample size estimation was calculated using the formula $n=Z^2P(1-P)/d^2$, in which n =required sample size, Z is a Z statistic value of 1.96 at confidence level of 95%, P =16%, estimated prevalence of HCC near by the study area and d = 0.05, relative precision. Thus, $n = (1.962)^2 \times 0.16 \times (1-0.16)/0.052 = 382$ households (one person per household). This number was more than doubled to adjust for multi-stage sampling design effect, thus, adjusted to = 872 for two districts. Participants were randomly selected from 42 villages of the two districts and the randomization was done at the villages and household level

2.3 Recruitment of participants and data collection

The survey was conducted in 42 randomly selected villages in the study districts. In order to recruit required participants, sensitization and mobilization meetings involving researchers and the community were conducted to explain purpose of the study. Households were selected randomly using excel sheet from an existing list of all households in the selected villages and selected participantss were asked for their consent to participate in the study. The selected households were visited for selection of eligible household member (aged between 15–60 years) to participate in the study. The study recruited equal number of households (20 households) per village for all 42 villages.

A structured questionnaire was developed and consisted of three parts: (i) general information of the household characteristics, such as age, sex, location, education level (ii) Behavioral information on pig rearing systems, presence and use of toilets, hand washing after defecation, washing of fruits and vegetables before consumption (iii) Clinical history on self-deworming and regular intestinal worm diagnosis. The questionnaires were administered to each of the 872 participants. After questionnaire administration, 5 ml venous blood was drawn from all participants at the cephalic or median cubital vein (median basilic vein) by a medical laboratory technician, the blood was collected in a specific plain blood vacutainer tube, well labelled and allowed to clot at room temperature overnight. At nearby village health centres, the clotted samples were centrifuged at 3500 rpm for serum extraction, ali-quoted and stored in cryogenic vials in freezers at -4^{o}C before analysis.

The laboratory analysis involved the use of immunological methods for the detection specific antibodies and for circulating parasite antigen in serum. Western blot IgG kit (WB-IgG) (LDBIO Diagnostics 69009 Lyon-France) was used for detection of specific antibodies (exposure) against HCC and the Cysticercosis Ag ELISA kit (Ag-Elisa) (apDia, Belgium) was used to detect circulating antigens (current infection) of *T. solium* cysticerci. The sensitivity and specificity of the Ag-ELISA for active infection with HCC has only been reported from a preliminary study conducted in Vietnam. The study indicated a sensitivity of 94.4% and a specificity of 100% for the diagnosis of current infection with cysticercosis (Dorny *et al.,* 2003, 2004).

For the Western blot IgG kit, reaction to one or all of the seven glycoprotein bands was considered a positive indication of cysticercosis or at least of exposure to *T. solium* among the 7 bands. These diagnostic bands are GP50, GP42-39, GP24, GP21, GP1S, GPI4, and GP13. The letters GP signify the glycoprotein nature of these antigens, and the numbers denote their respective molecular weights in thousands (Tsang, Brand and Boyer, 1989). Presence of *T. solium* cysticercus antigens in human serum was measured using a commercially available kit (apDia, Belgium). The Cysticercosis Western blot IgG kit and apDia cysticercosis Ag- ELISA were used according to the manufacturer's protocol supplied with the kit.

2.4 Diagnostic Definition of HCC cases

Clinical features for HCC are not specific. Therefore, definition of HCC cases is often based on immunodiagnostic methods (Flisser *et al.,* 2002). In this study, the definitions of HCC case have been considered as the active infection with viable cysticerci, therefore prevalence of infection is the proportion of respondents actively infected with viable cysticerci rather than prior exposure to *T. solium* in past, without active infection with living cysticerci. Also, the two testing methods were used for further indication of ‘hot spots’ in the study area where preventive and control measures should be applied.

2.5 Ethical Considerations

This study protocol was revised and approved by the Tanzania National Institute for Medical Research (NIMR) (NIMR/HQ/R.8a/Vol.1X/2802). The study also received approval from the ethics committee of the Klinikum rechts der Isar, Technical University of Munich, Germany, under the number of 537/18 S-KK. District authorities were asked for their consent to conduct the study. Consent for participation of the selected participants in a household was obtained from the selected individuals as well as the head of the household. Before sampling, each selected participant was approached individually to obtain written informed consent. For minors (<18 years) informed assents were obtained orally from them and thereafter a written informed consents were signed by their parents or guardians.

2.6 Statistical Analyses

Data entry and validation was carried out using Microsoft Excel 2010 (Ms Corp., Redmond, WA, USA). Then, descriptive analyses on the study population were conducted, followed by assessing the association between each potential risk factor and the prevalence of current HCC at the individual-level. Household characteristics measured through questionnaires were attributed to each individual since only one individual was sampled per household. All descriptive analyses were conducted using the SPSS version 24. To control confounding bias, Univariate logistic regression model was used to estimate association between current HCC seropositivity and other important risk factors using crude and adjusted odds ratios and their 95% confidence intervals. Statistical association was considered significant at $p < 0.05$.

3.0 Results

3.1 Socio demographic, behavioral and clinical factors

The socio-demographic, behavioral and clinical factors related to participants in the study villages are presented in Table 1. The total number of participants was 872, among them 593(68.0%) and 279(32.0%) were from Kongwa and Songwe District respectively. The majority 587(67.3%) of participants were males and based on education levels, majority 624(71.6%) had primary level of education. Based on pig rearing practices, most 857(98.2%) of the participants agreed to always observe free-roaming pigs in their community

Table 3. 1: Socio demographic, behavioral and clinical factors related to participants (N= 872)

Factor	n (%)
Social-demographic	
Districts	
Kongwa	593 (68.0)
Songwe	279 (32.0)
Sex	
Male	587 (67.3)
Female	285 (32.7)
Age	
15-25	72 (8.3)
26-45	444 (50.9)
>45 years	356 (40.8)
Educational level	
Informal	152 (17.4)
Primary	624 (71.6)
Secondary	77 (8.8)
Post-Secondary	19 (2.2)
Behavioural	
Water source	
Untreated	673 (77.2)
Treated	199 (22.8)
Pig rearing system	
Closed system	15 (1.7)
Free range system	857 (98.2)
Washing peeled fruits and vegetables	
No	80 (9.2)
Yes	792 (90.8)
Presence of toilets	
No	355 (40.7)
Yes	517 (59.3)
Every family member using toilet (n=517)	
No	34 (6.6)
Yes	483 (93.4)
Wash hands with soap after defecating	
No	293 (33.6)
Yes	579 (66.4)
Clinical	
Self-deworming	
No	404 (46.3)
Yes	468 (53.7)
History family member with Epilepsy	
No	340 (39.4)
Yes	522 (60.6)
Antibody presence	
No	851 (97.6)
Yes	21 (2.4)

3.2 Seroprevalence of *T. solium* cysticercosis

Seroprevalence of HCC was determined and related to selected demographic, behavioural and clinical factors as shown in Table. 2. Results indicated that out of 872 human sera examined, the Ag-ELISA detected 12 (1.4%) participants with active HCC. Also 21(2.4%) of participants were detected with antibodies indicating exposure to the *T. solium* cysticerci. The seropositivity varied depending on participants' listed factors, whereby majority 10 (2.8%) of participants with the age of above 45 years were detected with active HCC. Further findings indicated that, there was no significant difference in active HCC seropositivity between individual who had toilets at their household and those who hadn't.

Table 3. 2: Seroprevalence of human Cysticercosis across associated factors(N=872)

Factor		Antigen	P value		Antibody	P-value
	Yes (%)	No (%)		Yes (%)	No (%)	
Social-demographic						
Districts						
Kongwa	7 (1.2)	586 (98.8)	0.47	12 (2.0)	581 (98.0)	0.28
Songwe	5 (1.8)	274 (98.2)		9 (3.2)	270 (96.8)	
SexMale						
Female	11 (1.9)	576 (98.1)	0.117	20 (3.4)	567 (96.6)	0.004
	1 (0.3)	284 (99.7)		1 (0.4)	284 (99.6)	
Age						
15-25	0 (0.0)	72 (100)	0.015*	0 (0.0)	72 (100)	0.049*
26-45	2 (0.5)	442 (99.5)		7 (1.6)	437 (98.4)	
>45 years	10 (2.8)	346 (97.2)		14 (3.9)	342 (96.1)	
Educational level						
Informal	1 (0.7)	151(99.3)	0.648	1 (0.7)	151 (99.3)	0.160
Primary	11 (1.8)	613 (98.2)		20 (3.2)	604 (96.8)	
Secondary	0 (0.0)	77 (100.0)		0 (0.0)	77 (100.0)	
Post-Secondary	0 (0.0)	19 (100.0)		0 (0.0)	19 (100.0)	
Behavioural						
Water source						
Untreated	10 (1.5)	663 (98.5)	1.000	18 (2.7)	655 (97.3)	0.439
Treated	2 (1.0)	197 (99.0)		3 (1.5)	196 (98.5)	
Pig rearing system			0.189			
Closed	1 (6.7)	14 (93.3)		1(6.7)	14 (93.3)	0.341
Free range	11 (1.3)	846 (98.7)		20 (2.3)	837 (97.7)	
Presence of toilets						
No	3 (0.9)	352 (99.1)	0.378	5 (1.4)	350 (98.6)	0.121
Yes	9 (1.7)	508 (98.3)		16 (3.1)	501 (96.9)	
Family member using toilet	1 (2.9)	33 (97.1)		3 (4.0)	71(96.0)	0.413
No	8 (1.7)	475 (98.3)	0.271	18 (2.3)	780 (97.7)	
Yes						
Wash hands with soap after defecating						
No	2 (0.7)	291(99.3)	0.356	5 (1.7)	288 (98.3)	0.483
Yes	10 (1.7)	569 (98.3)		16 (2.8)	563 (97.2)	
Washing /peel fruits and vegetable						
No	2 (2.5)	78 (97.5)		3 (3.8)	77 (96.2)	
Yes	10 (1.3)	782 (98.7)	0.303	18 (2.3)	774 (97.7)	0.431
Clinical						
Self deworming						
No	7 (1.7)	397 (98.3)	0.562	10 (2.5)	394 (97.5)	1.000
Yes	5 (1.1)	463 (98.9)		11 (2.4)	457 (97.6)	
History family member with Epilepsy	4 (1.2)	336 (98.8)	0.773	6(1.8)	334 (98.2)	0.302
No	8 (1.5)	514 (98.5)		15(2.9)	507 (97.1)	
Yes						
Antibody presence	2 (0.24)	849 (99.8)	<0.001*	-	-	-
No	10 (47.6)	11(52.4)				
Yes						

*Chi square p-value < 0.05 from fisher`s exact test

3.3. Univariate analysis

Table 3.2 shows the univariate analysis results, whereby demographic, behavioural and clinical factors were associated with Ag-ELISA seropositivity, findings indicated that older age was a factor associated with active HCC, as the Ag-ELISA was higher in the age group of 45years and above (OR= 6.7) compared to other age groups. In addition, those who clinically were confirmed to have been exposed to the *T. solium* cysticerci in the past were more likely to be Ag-ELISA seropositive.

Table 3. 3: Associations between Ag-ELISA seropositivity and associated factors (N=872)

Characteristics	CrOR (95%CI)	*p*-value
Socio demographic		
Districts		
Kongwa	1	0.657
Songwe	1.52 (0.38,5.65)	
Sex		
Male	1	
Female	0.18 (0.00,1.28)	0.115
Age		
15-25		
26-45	1	
>45 years	6.71 (1.55,61.07)	0.005*
Educational level		
Informal	1	
Formal	0.89 (0.28,2.48)	1.000
Behavioral		
Water source		
Untreated	1	
Treated	0.67	0.920
Pig rearing system		
Closed	1	
Free range	0.18 (0.02,8.39)	0.378
Presence of toilets		
No	1	
Yes	2.08 (0.51,12.01)	0.418
Every family member using toilet	1	
No	0.56 (0.07,25.4)	0.542
Yes		
Wash hands with soap after defecating	1	
No	2.55 (0.54,24.13)	0.349
Yes		
Washing peeled fruits and vegetables	1	
No	0.50 (0.10,4.77)	0.606
Yes		
Clinical		
Self deworming		
No	1	0.582
Yes	0.61(0.15,2.26)	
History family member with Epilepsy	1	
No	1.31 (0.35,5.98)	0.907
Yes		
Antibody presence		
No	1	
Yes	361.71 (66.95,3766.02)	<0.001*

OR estimated from exact logistic regression
*Chi square p-value< 0.05 from fisher`s exact test

4.0 Discussion

The objective of this study was to estimate the seroprevalence of active HCC and assess factors associated with its transmission in villages of Kongwa and Songwe Districts. Previous studies indicated Kongwa and Songwe to be among the districts where PCC is endemic (Ngowi *et al.,* 2008; Komba *et al*., 2013 and Maganira *et al.,*2019). The sero-Ag ELISA assay detected HCC seroprevalence of 1.4% (n=12) indicating the presence of viable cysts and as such active infections in these individuals. Detection of this infection implies environmental contamination with *T. solium* eggs from human feces and fecal–oral infections due to the lack of clean and safe water or consumption of contaminated food. Furthermore, the study found participants aged between 45 year and above and those detected with IgG antibodies against HCC to be significantly associated with the active HCC.

Seroprevalence of HCC in this study is lower than those found by similar studies in Mbozi and Mbulu Districts of Tanzania whereby prevalence of HCC was 16% and 17% based on Ag-ELISA and Western blot IgG antibody detection assay respectively (Mwang'onde, Nkwengulila and Chacha 2012; Mwanjali *et al.* 2013). The low prevalence of HCC estimated in the present study may be contributed by the improved hygienic conditions as a result of established and ongoing national public health interventions such as Water Sanitation and Hygiene (WASH) and Mass Drug Administration (MDA), the latter targeting soil transmitted helminths and schistosomiasis (MoH, 2012; Thomas *et al*., 2013). A similar scenario has been reported in India (Vora *et al.* 2008). It was further established that age groups of the study population and presence of IgG antibodies for HCC were associated with HCC seropositivity, with higher prevalence in the age of 45 years years and above, compared to the younger ones. Similar findings have been reported by previous studies in Tanzania and India (Vora *et al.* 2008; Mwanjali *et al.* 2013). The study also associated the presence of IgG antibodies with presence of viable *T. solium* antigen and therefore presence of IgG antibodies does not confer protection against viable *T. solium* antigens. The differences in HCC seropositivity in age groups possibly reflect the effect of other interventions such as deworming program which is implemented mostly to school children excluding other age group (MoHSW, 2012), also levels of exposure to tapeworm eggs as age increases so as the likelihood of exposure status also increases. In village settings, elderly people spend more time in local beer bars located outside of their homes. This increases chances of eating undercooked and unhygienic food. However, such area has limited sources of safe and clean water, exposing them to acquiring infections including *T. solium* infections (Maridadi *et al.,*2011 and Mwanjali *et al.,*2012). Therefore, further studies need to be done to determine potential risk factors associated with these particular categories of population to find better solutions.

The use of immunodiagnostic methods (Ag- ELISA and Western Blot IgG) for estimation of the seroprevalence is pointed as a limitation in this study. Until now only a few of the current serological techniques have been standardized and fully validated. The validation of the tests is hindered by the lack of a gold standard for the diagnosis of HCC. Efforts should be made to make cheap, reliable and standardized immunodiagnostic tools more widely available, especially in developing countries.

5.0 Conclusion

Findings of this study indicate that HCC is prevalent in villages of Kongwa and Songwe districts of Tanzania, which are among the main pork suppliers in the country. Further, studies are needed in rural pig keeping communities for mapping of human *T. solium* infections and guide development of sustainable control measures with particular focus on elderly age groups and post exposure group as found to be a high risk groups while other measures are underway.

References

Afonso, S., Vaz, Y., Neves, L., Pondja, 1., Dias1, A., Willingham, M., Vilhena, P. Duarte, C. and Noor Mahomed. E. (2011). Human and porcine *Taenia solium* infections in Mozambique: identifying research priorities. *Anim Health Res Rev*; 12:123–9.

Arriola, C. S., Gonzalez, A. E., Gomez-Puerta, L. A., Lopez-Urbina, M. T., García, H. H. and Gilman, R. H. (2014). New insights in cysticercosis transmission. *PLOS Neglected Tropical Diseases* 8(10): e3247.

Carabin, H., Millogo, A., Cissé, A., Gabriël, S., Sahlu, I., Dorny, P., Bauer, C., Tarnagda, Z., Cowan, L. D. and Ganaba, R. (2015). Prevalence of and Factors Associated with Human Cysticercosis in 60 Villages in Three Provinces of Burkina Faso. Zhang W (ed.). *PLoS Negl Trop Dis* 2015;9: e0004248.

Carabin, H., Millogo, A., Cissé, A., Gabriël, S., Sahlu, I., Dorny, P., Bauer, C., Tarnagda, Z., Cowan, L. D. and Ganaba, R. (2015). Prevalence of and factors associated with human cysticercosis in 60 villages in three provinces of Burkina Faso. *PLOS Neglected Tropical Diseases* 9(11): e0004248.

Deckers, N. and Dorny, P. (2010). Immunodiagnosis of *Taenia solium* taeniosis/cysticercosis. *Trends in Parasitology* 26(3): 137–144.

Dohoo I.R., Martin, S.W. and Stryhn, H. (2009) *Veterinary Epidemiologic Research*. Charlottetown, P.E.I.: VER, Inc.

Dorny, P., Brandt, J. and Geerts, S. (2004b). Immunodiagnostic approaches for detecting *Taenia solium*. *Trends in Parasitology* 20(6): 259–260.

Eom, K. S., Chai. J.Y. and Yong T-S*.* (2011)*.* Morphologic and Genetic Identification of *Taenia* Tapeworms in Tanzania and DNA Genotyping of *Taenia solium*. *The Korean Journal of Parasitology*; 49:399.

Flisser, A., Rodríguez-Canul, R. and Willingham. M. (2006). Control of the taeniosis/cysticercosis complex: Future developments. *Veterinary Parasitology*; 139:283–92.

García, H. H, Gonzalez, A. E., Evans, C. A., Gilman, R. H. and Cysticercosis Working Group. (2003b)*. Taenia solium* cysticercosis. *Lancet*; 362: 547–56.

González, L. M., Villalobos, N., Montero, E., Morales, J., Sanz, R. A., Muro, A., Harrison, L. J. S., Parkhouse, R. M. E. and Gárate, T. (2016). *l.* Pathogenesis of *Taenia solium* taeniasis and cysticercosis. *Parasite Immunol*; 38:136–46.

Mwang'onde, B., Nkwengulila, G. and Chacha, M. (2012). The Serological Survey for Human Cysticercosis Prevalence in Mbulu District, Tanzania. *Advances in Infectious Diseases*; 02:62–6.

Komba, E. V. G., Kimbi, E. C., Ngowi, H. A., Kimera, S. I., Mlangwa, J. E., Lekule, F. P., Sikasunge, C. S., Willingham, A. L., Johansen, M. V. and Thamsborg, S. M. (2013). Prevalence of porcine cysticercosis and associated risk factors in smallholder pig production systems in Mbeya region, southern highlands of Tanzania. *Veterinary Parasitology*; 198:284–91.

Mafojane, N. A., Appleton, C. C., Krecek, R. C., Michael, L. M. and Willingham, A. L. (2003)*.* The current status of neurocysticercosis in Eastern and Southern Africa. *Acta Trop*; 87:25–33.

Maganira, J. D., Hepelwa, N. I. and Mwang'onde, B. J. (2018). Seroprevalence of Porcine Cysticercosis in Ludewa District, Njombe, Tanzania. *Advances in Infectious Diseases*; 08:151.

Maganira, J. D., Mwang'onde, B. J.and Kidima. W. (2019). Seroprevalence of circulating taeniid antigens in pigs and associated risk factors in Kongwa district, Tanzania. *Parasite Epidemiology and Control*;7: e00123.

Maridadi, A. F., Lwelamira, J. and Simime, F.G. (2011). Knowledge and Practices Related to *T. solium* Cysticercosis - Taeniasis among Smallholder Farmers in Selected Villages in Kilolo District in Iringa Region in Southern Highlands of Tanzania. *International Journal of Animal and Veterinary Advances 3(3):* 196-201*.*

Mwang'onde, B. J., Nkwengulila, G. and Chacha, M. (2014). The risk factors for human cysticercosis in Mbulu District, Tanzania. *Onderstepoort J Vet Res*; 81, DOI: 10.4102/ojvr. v81i2.719.

Mwanjali, G., Kihamia, C., Kakoko, D. V. C., Lekule, F., Ngowi, H., Johansen, M. V., Thamsborg, S. M. and Willingham, A. L. (2013). Prevalence and Risk Factors Associated with Human Taenia Solium Infections in Mbozi District, Mbeya Region, Tanzania. Jones MK (ed.). *PLoS Neglected Tropical Diseases*;7: e2102.

National Bureau of Statistics—2012 PHC: Regional Profiles. Available online: [https://www.nbs.go.tz/index.php/en/regionalprofiles]. [Accessed on 1/11/ 2020].

National Bureau of Statistics—Agriculture Statistics. Available online: [https://www.nbs.go.tz/index.php/en/census-surveys/ agriculture-statistics]. [Accessed on 28/7/ 2021).

Ndimubanzi, P. C., Carabin, H., Budke, C. M., Nguyen, H., Qian, Y.-J., Rainwater, E., Dickey, M., Reynolds, S. and Stoner, J. A. (2010). A Systematic Review of the Frequency of Neurocyticercosis with a Focus on People with Epilepsy. Preux P-M (ed.). *PLoS Neglected Tropical Diseases* ;4: e870.

Ngowi, H. A, Kassuku, A. A., Maeda, G. E. M., Boa, M. E., Carabin, H. and Willingham, A. L.(2004b). Risk factors for the prevalence of porcine cysticercosis in Mbulu District, Tanzania. *Veterinary Parasitology*; 120:275–83.

Ngowi, H. A., Winkler, A. S., Braae, U. C., Mdegela, R. H., Mkupasi, E. M., Kabululu, M. L., Lekule, F. P. and Johansen, M. V. (2019). *Taenia solium* taeniosis and cysticercosis literature in Tanzania provides research evidence justification for control: A systematic scoping review. Devleesschauwer B (ed.). *PLoS ONE*;14: e0217420.

Phiri, I. K., Ngowi, H., Afonso, S., Matenga, E., Boa, M., Mukaratirwa, S., Githigia, S., Saimo, M., Sikasunge, C., Maingi, N., Lubega, G. W., Kassuku, A., Michael, L., Siziya, S., Krecek, R. C., Noormahomed, E., Vilhena, M., Dorny, P. and Lee Willingham III, A. (2003). *I.* The emergence of *Taenia solium* cysticercosis in Eastern and Southern Africa as a serious agricultural problem and public health risk. *Acta Tropica*; 87:13–23.

Praet, N., Speybroeck, N., Rodriguez–Hidalgo, R., Benitez-Ortiz, W., Berkvens, D., Brandt, J., Saegerman, C. and Dorny, P. (2010a).: How Does Pork Trade Affect the Transmission of the Parasite? Garcia HH (ed.). *PLoS Negl Trop Dis*;4: e817.

Sikasunge, C. S., Phiri, I. K., Phiri, A. M., Dorny, P., Siziya, S. and Willingham, A. L. (2008). Prevalence of *Taenia solium* porcine cysticercosis in the Eastern, Southern and Western provinces of Zambia. *Vet J*; 176:240–4.

Sohrabi. M., Amin. R., Maher. A., Amin1. R., Maher, A and Ali, R. (2021). Sociodemographic determinants and clinical risk factors associated with COVID-19 severity: a cross-sectional analysis of over 200,000 patients in Tehran, Iran. *BMC Infectious Diseases*; 21:474.

Thomas, L. F., de Glanville, W. A., Cook, E. A. and Fèvre, E. M. (2014). Epidemiology of *Taenia solium* Cysticercosis in western Kenya. *BMC Veterinary Research* 9(1): 46.

Trevisan, C., Devleesschauwer, B., Schmidt, V., Winkler, A. S., Harrison, W. and Johansen, M. V. (2017). Are we ready for *Taenia solium* cysticercosis elimination in sub-Saharan Africa? *Parasitology*; 144:59–64.

Tsang, V. C., Brand, J. A. and Boyer, A. E. (1989). An enzyme-linked immunoelectrotransfer blot assay and glycoprotein antigens for diagnosing human cysticercosis (*Taenia solium*). *The Journal of Infectious Diseases* 159(1): 50 – 59.

Vora SH, Motghare DD, Ferreira and Frediric, S. (2008). High Prevalence of Human Cysticercosis in a Rural Village in Western India. *Tropical Medicine and Health*; 36:137–8.

WHO. (2016). Preventable epilepsy: *Taenia solium* infection burdens economies, societies and individuals. World Health Organization (WHO), Geneva. 191pp.

Winkler, A. S. (2012). Neurocysticercosis in sub-Saharan Africa: A review of prevalence, clinical characteristics, diagnosis, and management. *Pathogens and Global Health* 106(5): 261–274.

Winkler, A.S., Blocher. J. and Auer. H. (2009). Epilepsy and neurocysticercosis in rural Tanzania—An imaging study. *Epilepsia*; 50:987–93.

CHAPTER FOUR

Paper III

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Paper published in:
Pathogens (MDPI)

pathogens MDPI

Article

Community Health-Education Intervention Trial against Human *Taenia solium* Taeniasis/Cysticercosis in Central and Southern Zones of Tanzania

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Abstract: Poor knowledge of human *T. solium* taeniasis/cysticercosis and insufficient sanitary and hygienic practices have been associated with the persistence of human *T. solium* infections in endemic areas. Community health education intervention measures were implemented in 42 villages of Kongwa and Songwe Districts to increase knowledge, improve good practices against infection and reduce incidences of human cysticercosis transmission using a health education package. The health education package comprised of leaflet, poster and a booklet The 42 villages were allocated into intervention group and control group, and each group consisted of 21 villages. Baseline and post-intervention information on social demography, knowledge, safe practices and incidences of human cysticercosis was collected from both village groups. The impact of the intervention was evaluated by comparing changes in knowledge, preventive practices related to human *T. solium* infections and the cumulative incidence of human cysticercosis between intervention and control villages. There was no significant difference in mean knowledge scores and preventive practice mean scores between the control and intervention groups at baseline. However, there were significantly higher knowledge mean scores in the intervention group compared to the control group at one year post-intervention (2.06 ± 1.45 vs. 0.94 ± 1.18, $p < 0.001$). There was no significant difference in the mean practice scores between the intervention and the control group at one year post-intervention (2.49 ± 1.13 vs. 2.40 ± 1.13, $p = 0.31$). Furthermore, there was no significant difference in the prevalence of human *T. solium* cysticercosis between the intervention and the control group at the baseline (1.4% vs. 1.4%, $p = 0.97$) by Ag-Elisa, and at one year post-intervention the cumulative incidence of human cysticercosis was 1.9 and 1.2 per cent in the control and intervention group, respectively. There was no significant difference in the cumulative incidence of human cysticercosis between the intervention and the control group at one year post-intervention ($p > 0.05$). Community health-education intervention is effective at improving the knowledge of human *T. solium* infections. The improvement in preventive practices and reduction in incidences of human cysticercosis are a gradual process, they may require sanitary and hygienic improvement and more time after the intervention to see improved changes. The study recommends a sustainable public health education on *T. solium* infections using the health education package through one health approach.

Keywords: human; Taeniosis; cysticercosis; education; intervention; neglected diseases

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Citation: Makingi, G.; Ngowi, B.; Mkupasi, E.; Wilson, C.; Winkler, A.S.; Nzalawahe, J.; Ngowi, H. Community Health-Education Intervention Trial against Human *Taenia solium* Taeniasis/Cysticercosis in Central and Southern Zones of Tanzania. *Pathogens* **2023**, *12*, 955. https://doi.org/10.3390/pathogens12070955

Academic Editors: Ali Raza, Andrew Richard Williams and Timothy G. Geary

Received: 3 February 2023
Revised: 18 April 2023
Accepted: 9 June 2023
Published: 20 July 2023

1. Introduction

Taenia solium-taeniasis and cysticercosis (TSTC) are diseases mostly endemic in developing countries, associated with poverty, poor hygiene, inadequate sanitation and unrestricted pig movement [1]. Humans can harbour the adult intestinal tapeworm (taeniasis), the sole natural definitive host, acquired by eating raw or undercooked infected pork. Infective eggs are shed by human carriers via the stool and contaminate the environment. Pigs are significant intermediate hosts and are infected by ingestion of these infective eggs (or proglottids), which develop into porcine cysticercosis (PCC). Humans act as intermediate dead-end hosts, where cysts can develop in muscles leading to human cysticercosis (HCC) and upon reaching the central nervous system (CNS) leads to neurocysticercosis (NCC) [2]. Although the manner in which eggs are ingested is not usually known, the tapeworm carriers and close household contacts are at the greatest risk, suggesting that person-to-person spread is important. However, the contamination of food and water also occurs. Thus, HCC can occur in individuals who do not raise pigs or consume pork [3]. The burden of *T. solium* infection is mainly due to the public health effects of NCC and economic losses due to associated treatment. The World Health Organization (WHO) estimated *Taenia* infections to have infected approximately 50 million people annually and to kill 50,000 [1]. The infections are endemic in many countries of sub–Saharan Africa (SSA), Asia and Latin America [4,5].

In most endemic areas, the infection and disease remain uncontrolled because of a lack of information and awareness about the extent of the problem and the absence of suitable diagnostic tools and intervention strategies adapted to the local situation [6]. Recent epidemiologic studies carried out in some areas in Tanzania revealed that significant cases of human *T. solium* infections of up to 17 per cent of cases of HCC have been reported in rural and urban populations [7,8], and identified poor knowledge and risky practices to be associated with transmission [7,9,10]. In Tanzania, the number of disability-adjusted life years (DALYs) per thousand person years for NCC-associated epilepsy was estimated to be 0.7 for the year 2012. The annual number of NCC-associated epilepsy incident cases and deaths were 17,853 and 212, respectively [11]. Additionally, around five million USD were spent due to NCC-associated epilepsy, comprising direct and indirect costs due to hospitalizations, visits to the hospitals/doctors and the cost of drugs/medicines [1]. Control measures recommended to combat this disease include improvements in hygiene, sanitation, pig management, mass taeniacidal chemotherapy and health education [12]. However, there are limited community studies on the evaluation of such interventions in endemic countries, Tanzania included, where only one study has been carried out to assess the impact of health education on the prevalence or incidence of *T. solium* infections. The study observed a decrease in the incidence of PCC about one year after a health-education intervention, as assessed by Ag-ELISA using sentinel pigs. In this study, the increase in knowledge did not significantly change observed behaviour [13]. Health education is the cornerstone of health promotion and has been defined as the lifelong process by which individuals acquire knowledge, attitudes and behaviour that promote health and foster wise decisions for solving personal, family and community health problems [14]. Furthermore, health educational intervention is highly encouraged because it might lead to permanent changes towards controlling and eventually eliminating the infections. Based on a study performed in the Mbulu, Mpwapwa and Mbinga Districts in Tanzania where knowledge regarding TSTC was low, researchers identified certain key messages from the community [15] leading to the development of a community-based health education intervention package for preventing and controlling TSTC.

This study hypothesized that imparting specific health education to the community regarding human TSTC would increase their knowledge, improve their preventive practices against the infection and eventually reduce incidences of HCC in endemic areas. Therefore, the study was designed to evaluate the effectiveness of a locally developed health education trial against human *Taenia solium* taeniasis/cysticercosis in villages of the Kongwa and Songwe Districts representing the central and the southern zones of Tanzania, respectively.

2. Materials and Methods

2.1. Study Area

The survey was conducted from September 2019 to December 2021 in the villages of the Songwe and Kongwa Districts of Tanzania. The districts were selected purposefully based on known *T. solium* infection endemicity and accessibility [7,16–18]. Songwe District is located in the southern highlands of Tanzania with an altitude ranging from 900 to 2750 m above sea level, between latitude 8°11′ to 57°84′ south of the equator and longitude 32°53′ to 41°10′ east of Greenwich Meridian. This district covers an area of 16,070 square kilometres composed of 43 villages. It has an estimated population of 157,089 people within 28,282 households. The main occupational activities include agriculture, mining and other informal sectors. The mean temperature is about 26.5 °C. The district has one rainy season from November to May, which records 750 to 2000 mm per annum [19].

Kongwa District is located in the central zone of Tanzania at a latitude of 5°30′ to 6°00′ south of the equator and longitudes 36°15′ to 36°00′ east of the Greenwich Meridian. Its height ranges between 900 and 1000 m above the main sea level. This district has an area of 4041 square kilometres. It is composed of 87 villages, with an estimated human population of 365,952 composed of 61,914 households [19]. The occupational activities of inhabitants are agriculture and other informal sectors. The mean temperature is about 26.5 °C and the rainy season is from November to April, with an average annual rainfall of 500 to 800 mm [20].

2.2. Study Design

The study adopted a cluster-randomised control trial with pre- and post-intervention assessments of study subjects. The study assessed a total of 93 and 43 villages in the Kongwa and Songwe Districts, respectively, for their eligibility to participate in the study to include 42 eligible and virtually independent villages as per the previous similar study in the southern zone of the country [13]. Eligibility criteria for a village to participate in the study included pig-keeping activities and the willingness of the community to participate in the study. The eligibility criteria were met by all 136 villages. A list of all villages including their pig population was obtained and each village was assigned a unique number; using Microsoft Excel, a random sampling procedure was performed whereby 42 villages were randomly selected and enrolled in the study.

2.3. Sample Size Estimation and Selection of the Household

The sample size estimation was calculated using the formula $n = Z^2PQ/L$ [21], where n is the required number of individuals to be enrolled, Z is the Z-score for a given confidence level, P is a known or estimated prevalence, Q = (1 − P), and L the allowable error of estimation. In the current study, 95 per cent was used as the confidence level with an allowable error of estimation of 0.05. $p = 16$ per cent, the estimated prevalence of HCC nearby the study area [7], and d = 0.05, the relative precision. Thus, $n = 1.96^2 \times 0.16 \times (1 - 0.16)/0.05^2 = 382$ households (one person per household). This number was more than doubled to adjust for dropout during the study and multi-stage sampling design effect and, thus, adjusted to = 872 for the two districts. Participating households were randomly selected from 42 villages in the two districts.

Before the beginning of the study, sensitization and mobilization meetings involving researchers and community leaders were conducted, in which the study objectives were explained. A list of all village households who agreed to participate was obtained, and by using Microsoft Excel Window 10 households for inclusion in the survey were randomly selected. Then, the research team visited the selected households with support from the household head, the eligible household representative were identified to participate in the study. The criteria of eligibility were being a permanent household member, aged between 15–60 years and the willingness to participate.

2.4. Data Collection

A total of 42 villages were studied (28 from Kongwa and 14 from Songwe). The baseline study recruited a total of 872 households (513 from Kongwa and 279 from Songwe). During the post-intervention study, a total of 210 households were lost to follow-up (98 from the intervention group and 122 from the control group) due to various reasons, including death and migration to other areas, and some of the respondents refused to continue. The flow of participation is summarized in Figure 1.

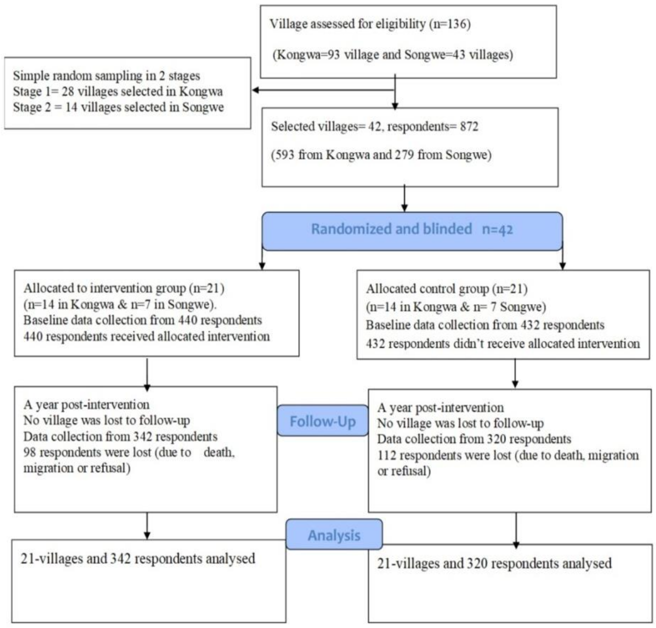

Figure 1. The flow of respondents in a randomized control trial to assess the effect of health-education intervention in the Songwe and Kongwa Districts, Tanzania, 2019–2021.

2.4.1. Scheme Diagram of Sample Collection

The study collected the data in three key phases: it was first collected between July and September 2019 in the selected villages of the two aforementioned districts during a baseline survey, followed by the health educational intervention which lasted for two months (September and November 2020). The survey was repeated between September and December 2021, a year after the education intervention, whereby data were collected to evaluate the effect of the health education intervention in improving knowledge and preventive practices against human TSTC among community members.

2.4.2. Baseline Survey

The baseline study was conducted between July 2019 and September 2019 to collect information through face-to-face interviews with household heads or representatives. The information was collected using KoboCollect; the application for data collection through KoBoToolBox (Kobo Collect v.1.27.3-3) [22] was downloaded from Google Play Store and installed on Android tablets. The tool was used for the formulation of questionnaires and data collection. The questionnaire was designed based on the WHO guide for developing knowledge, attitude and practices (KAP) surveys [23] and included both closed- and open-ended questions. Two investigators were trained on the use of KoboCollect tool before the commencement of the study. The investigators also pre-tested the feasibility and correctness of the items in the electronic questionnaire. The explored information included social-demographic characteristics, knowledge of human TSTC transmission, symptoms, preventive measures, treatment options and sanitary and hygienic practices as detailed in Table 1. The questionnaire responses were supplemented with direct observation during visits to the households. The questions were phrased according to the local circumstances and Kiswahili language was used to provide the information. After the questionnaire survey, 5 mL venous blood was drawn from all participants who also consented to the serological component of the study. The blood sample was drawn at the cephalic or median cubital vein (median basilic vein) by a medical laboratory technician; the blood was collected in a specific plain blood vacutainer tube. The tubes were placed in a cooler, and left to decant, and the sera were collected and put in two pre-labelled tubes at the end of each day or the following day. The sera were placed in freezers (−20 °C) after the blood draw, and then brought to the laboratory (Public health research laboratory) and kept in a freezer at −20 °C until the analyses were carried out at the College of Veterinary Medicine and Biomedical Sciences laboratories. The serum samples were tested for the presence of excretory circulating antigens of the metacestode of *T. solium* using enzyme-linked immunosorbent assay (Ag-ELISA) [24–26]. The test was found to have a sensitivity of 94.4 per cent (95% CI: 80–99%) and a specificity of 98 per cent (95% CI: 90–99%) to detect current infection in a study conducted in Vietnam and Ecuador [27]. With Ag-ELISA, no cross-reactions were observed in sera from patients with confirmed infections with *Schistosoma*, hydatid cysts, *Ascaris*, *Trichuris*, filaria, *Entamoeba*, *Plasmodium* and *Trypanosoma* [28].

Table 1. Socio-demographic, behavioural and clinical characteristics at baseline (N = 662).

Characteristic	*Control (%) (n = 324)*	**Intervention (%)** (*n* = 338)	**Chi Test**	***p*-Value**
Socio-demographic				
Sex				
Male	230 (71.0)	220 (65.1)	2.644	0.104
Female	94 (29.0)	118 (34.9)		
Age (years)				
15–25	15 (4.6)	12 (3.6)	4.797	0.091
26–45	131 (40.4)	165 (48.8)		
>45	178 (55.0)	161 (47.6)		
Educational level				
Informal	250 (77.2)	255 (75.4)	1.156	0.764
Primary	24 (7.4)	31 (9.2)		
Secondary	7 (2.2)	5 (1.5)		
Post-Secondary	43 (13.2)	47 (13.9)		
Knowledge				
Awareness of Human TSTC				
No	283 (87.4)	290 (85.8)	0.340	0.560
Yes	41 (12.6)	48 (14.2)		
Human consumption of PCC-infected pork is safe				
No	30 (9.3)	34 (10.1)	0.121	0.728
Yes	294 (90.7)	304 (89.9)		

Table 1. *Cont.*

Characteristic	Control (%) (*n* = 324)	Intervention (%) (*n* = 338)	Chi Test	*p*-Value
T. solium infect both human and pigs.				
No	306 (94.4)	309 (91.4)	2.294	0.130
Yes	18 (5.6)	29 (8.6)		
Human TSTC be prevented				
No	219 (67.6)	221 (65.4)	0.361	0.547
Yes	105 (32.4)	117 (34.6)		
Human TSTC can cause epilepsy/seizures.				
No	313 (96.6)	316 (93.5)	3.386	0.066
Yes	11 (3.4)	22 (6.5)		
Practice				
Pigs roam freely in open fields				
Closed system	6 (1.9)	4 (1.2)	0.497	0.481
Freely roaming	318 (98.1)	334 (98.8)		
Always observe human faeces around the premises				
No	160 (49.4)	162 (47.9)	0.140	0.708
Yes	164 (50.6)	176 (52.1)		
Presence of toilet in household				
No	132 (40.7)	129 (38.2)	0.459	0.498
Yes	192 (59.3)	209 (61.8)		
Washing hands with soap after defecation				
No	99 (30.6)	109 (32.3)	0.220	0.639
Yes	225 (69.4)	229 (67.8)		
Use official water sources				
No	260 (80.2)	269 (79.6)	0.045	0.832
Yes	64 (19.8)	69 (20.4)		

2.4.3. Community Health Education Intervention

The intervention consisted of a health-educational package (leaflets, booklets, posters, and a training manual) which was developed during a previous sociological study, conducted in Mbulu, Mpwapwa and Mbinga Districts in Tanzania where knowledge regarding TSTC was low. Researchers identified certain key messages from the community [15] leading to the development of the package for preventing and controlling TSTC. Videos and pictures were locally produced to increase the understanding of both literate and illiterate respondents. The training manuals were made more pictorial than text to enable illiterate respondents to follow the messages. The training was given at the village level whereas the respondents from control villages received only routine community health services. The education intervention was implemented in two phases; the first phase involved 2 days of training for 10–15, with the trainers including livestock/agricultural extension officers, school teachers, health workers and village leaders to serve as local trainers for sustainability purposes. The trainers also suggested improvements to the package to better fit the local situation. The second phase of the intervention was implemented by involving the general public in the intervention group. All respondents were invited to attend 2 days of training at a chosen village-level location. During the training sessions, the trainers with support from the researchers trained respondents using the health-education package. The package was mainly composed of three modules which included a module on knowledge of TSTC and transmission dynamics, a module on hygienic and sanitary practices associated with TSTC, and the last module was on proper pig management. The trainer later distributed a leaflet and a booklet to each household owner. The seminars were conducted in village offices, school classrooms, churches and other available places.

2.4.4. Post-Health Education Intervention Survey

One year after the health education training, the questionnaire survey and direct observations were repeated in all households of the 42 study villages, recruiting the same respondents and assessing the same factors as during the baseline study. A total of 872 and 662 participants from the study villages were surveyed at the baseline and post-intervention, respectively. Again, after the questionnaire survey, the serological survey was repeated. However, this survey involved only participants who were Ag-Elisa-negative at the baseline.

2.5. Statistical Analysis

Data were imported from the KoBoCollect toolbox into Microsoft Excel for cleaning. The data were then transferred to IBM Statistical Package for Social Sciences (SPSS version 20.0) for statistical analysis. This analysis involved only households that participated in both the baseline and the post-intervention studies, hereby referred to as "full participants". The statistical methods used in this work were conducted in three steps. (1) McNemar's Chi-Square tests were conducted to examine the equilibrium of demographic characteristics (sex, age, location of participant and educational level) at baseline. (2) The frequency of correct answers on the knowledge and preventive practice variables regarding human TSTC and (3) the mean scores on knowledge and preventive practices, each question having an equal weight of knowledge and preventive practices, the mean scores were compared between intervention and control groups through Sharpiro-Wilk test, T-test and Wilcoxon test. In addition, the cumulative incidence of HCC was compared between the intervention and control groups taking into account their baseline prevalence levels.

3. Results

3.1. Socio-Demographic Characteristics of Respondents at Baseline

The socio-demographic characteristics of participants at baseline in the control and intervention group are presented in Table 1. The total number of participants at baseline and post-intervention was 662, whereby 324 (48.9%) and 338 (51.1%) participants were in the control and intervention groups, respectively. The majority of participants in both groups were males: 230 (71.0%) and 220 (65.1%) from the control and intervention groups, respectively. At baseline, a total of 41 (12.6%) and 48 (14.2%) participants were found to be aware of the infection in the control and intervention groups, respectively. Based on preventive practices, a total of 318 (98.1%) and 334 (98.8%) from the control and intervention groups, respectively, agreed to always observe free-roaming pigs in their community.

3.2. Post-Intervention Comparison of Knowledge and Preventive Practices in the Control and Intervention Groups

The proportions of respondents who were able to respond correctly to the given questions following the community health education intervention are shown in Table 2. Regarding awareness of human *T. solium* infections, 60 (18.5%) and 206 (60.9%) of the respondents from the control and intervention groups, respectively, reported to have been aware of the infections. From the intervention group, 159 (47.8%) participants agreed that human epilepsy could be caused by *T. solium* infection compared to 56 (17.4%) participants from the control group. The results also indicated that 115 (34.0%) participants from the intervention group were using official water sources for domestic purposes compared to 75 (23.1%) participants from the control group who were using unofficial water sources (Table 2).

Table 2. Post-intervention knowledge and practice related to human TSTC transmission between the intervention and control groups (N = 662).

Characteristic	Control (%)	Intervention (%)	Chi Test	*p*-Value
Knowledge				
Awareness of Human TSTC				
No	264 (81.5)	132 (39.1)	123.895	<0.001
Yes	60 (18.5)	206 (60.9)		
Human consumption of PCC-infected pork is safe				
No	323 (99.7)	337 (99.7)	0.0001	0.976
Yes	1 (0.3)	1 (0.3)		
T. solium infect both human and pigs.				
No	273 (84.3)	229 (67.8)	24.600	<0.001
Yes	51 (15.7)	109 (32.2)		
Human TSTC be prevented				
No	204 (63.0)	93 (27.5)	84.035	<0.001
Yes	120 (37.0)	245 (72.5)		
Human TSTC can cause epilepsy/seizures.				
No	266 (82.6)	174 (52.3)	68.415	<0.001
Yes	56 (17.4)	159 (47.8)		
Practise				
Pigs roam freely in open fields				
Closed system	172 (53.1)	223 (66.0)	11.42	<0.001
Freely roaming	152 (46.9)	115 (34.0)		
Always observe human faeces around the premises				
No	100 (30.9)	127 (37.6)	3.305	0.069
Yes	224 (69.1)	211 (62.4)		
Presence of toilet in household				
No	178 (54.9)	163 (48.2)	2.985	0.084
Yes	146 (45.1)	175 (51.8)		
Washing hands with soap after defecation				
No	146 (45.)	115 (34.0)	8.835	0.003
Yes	176 (54.7)	223 (66.0)		
Use official water sources				
No	249 (76.9)	223 (66.0)	9.562	0.002
Yes	75 (23.1)	115 (34.0)		

Significant at $p < 0.05$.

3.3. Mean Knowledge and Preventive Practice Scores Regarding Human TSTC at Baseline and Post-Intervention

Knowledge Mean Scores

The results showed that there was no significant difference in knowledge mean scores between the control and intervention groups (1.54 ± 1.02 vs. 1.45 ± 0.94, $p = 0.24$) at baseline. However, there was significantly higher knowledge mean scores in the intervention group compared to the control group a year post-intervention (2.06 ± 1.45 vs. 0.94 ± 1.18, $p < 0.001$). The results also showed that there was no significant difference in practice mean scores between the intervention and the control group (3.01 ± 0.06 vs. 2.98 ± 1.01, $p = 0.678$) at baseline. Despite the education intervention given, there was also no significant difference in practice mean scores between the intervention and the control group a year post-intervention (2.49 ± 1.13 vs. 2.40 ± 1.13, $p = 0.31$) (Table 3).

Table 3. Comparison of mean scores before and after the intervention between the Control and Intervention groups (N = 662).

Variable	Group	Pre-Intervention Mean ± SD	p-Value	Post-Intervention Mean ± SD	p-Value
Knowledge	Control	1.45 ± 0.94	0.235	0.94 ± 1.18	<0.001
	Intervention	1.54 ± 1.02		2.06 ± 1.45	
Practice	Control	2.98 ± 1.01	0.678	2.40 ± 1.13	0.306
	Intervention	3.01 ± 0.06		2.49 ± 1.13	

Upon the Sharpiro–Wilk test, the pre-intervention scores were not normally distributed but post-intervention scores were normally distributed. A *t*-test and Wilcoxon signed-rank test were used for comparison (due to the central limit theorem, with a sample size of more than 30, a paired *t*-test can also be used) and the *p*-value remained similar in each. Significance set at $p < 0.05$.

3.4. Prevalence of Human Cysticercosis before and Cumulative Incidence after the Health Educational Intervention

The prevalence of HCC showed no significant difference at baseline between the intervention and control groups as measured by Ag-Elisa in the serum sample (Table 4). The comparison of cumulative incidence of the infection between control and intervention villages a year after an intensive health education intervention showed no statistically significant reduction in new infection cases between the control and intervention groups.

Table 4. Prevalence of HCC before and cumulative incidence after the intervention in the control and intervention villages.

Group	Pre-Intervention			Post-Intervention		
	(n = 872)	Prevalence (%)	p-Value	(n = 662)	Incidence (%)	p-Value
Control	432	6 (1.4)	0.97	324	6 (1.9)	0.48
Intervention	440	6 (1.4)		338	4 (1.2)	

4. Discussion

This was a randomized, controlled, community-based health-education intervention trial for the control of human *T. solium* infections conducted in an area where the infection is endemic [7,18]. The study utilized health-education intervention as a strategy to increase knowledge, improve preventive practices against human TSTC and ultimately reduce the cumulative incidence of HCC among community members in the selected intervention villages of Kongwa and Songwe District [13,29,30]. The comparison of the pre–post-randomisation change in knowledge, preventive practice and cumulative incidence between the control and intervention groups helped us to freely study the effect of the intervention itself, given that an individual's behaviour can be altered because the individual knows that he/she is being studied, known as the "Hawthorne effect" [13,31,32]. The observed changes in the outcomes could be attributed to the effect of the intervention delivered to the target villages.

This study and other studies have consistently shown that the knowledge regarding *T. solium* infections is poor, resulting in an increase in infection transmission, and hence recommends specific and targeted education among this at-risk group [7,13,33,34]. At the baseline, this study revealed that most of the participants in intervention and control groups had limited knowledge of human cases of TSTC as the infection was always mentioned in pigs. Additionally, the majority of the participants had limited knowledge of the life cycle of the parasite, believing that it was safe for humans to consume PCC-infected pork. In addition, the majority of the participants did not know that the life cycle of the parasites involves humans and pigs. Considering clinical signs associated with the infection, the majority of the participants did not know that HCC may result in an epileptic condition. Furthermore, most participants did not have knowledge of prevention and control measures against the infection, as they believed that the infection could not be prevented. Additionally, the baseline surveillance revealed the existence of risk practices associated with human TSTC in both groups: as noted, there were massive unrestricted pig movements in both the control and intervention villages. Free-range pig management increases the chances of TSTC transmission in most endemic areas of the country [13,18,33,34]. Additionally, the study observed excessive domestic use of unofficial water sources due to limited official water sources in the study area. This practice is common in most villages of the country where the supply of safe and clean water was not adequate [35], which might have subjected the community to acquiring infectious diseases including HCC. In addition, the majority of participants reported having spotted human faeces around their premises; this practice might cause environmental contamination with various infectious agents including *T. solium* eggs from human *T. solium* carriers. The baseline study also revealed the prevalence of HCC in the study villages, whereby further findings indicated that there was no significant difference in the prevalence between the control and intervention villages. However, the reported prevalence in this study was low compared to previous studies in the country. This might be due to differences in the study design, clinical characteristics of the study population and the diagnostic methods used [7,8]. Health education is the cornerstone of health promotion and has been defined as the lifelong process by which individuals acquire knowledge, attitudes and behaviour that promote health and foster wise decision making for solving personal, family and community health problems [14].

Following the health-education training in the intervention villages, the results of this study showed different mean scores between the control and intervention. There was significantly higher knowledge mean scores in the intervention group compared to the control group, showing an improvement in knowledge among respondents who received the intervention. The intervention resulted in an increase in the knowledge of human TSTC in the intervention group compared to the control group. Likewise, knowledge on the life cycle of the parasite was increased in the intervention group as every participant knew the risk for humans to consume PCC-infected pork. In addition, most of the trained participants agreed that human TSTC could be prevented at the community level after learning of the transmission cycle. This study is in agreement with a previous study that evaluated the effect of health education in improving knowledge and practices related to the transmission of PCC in Mbulu District, northern Tanzania [13], between which the training materials delivery mode. Another community-based study in Mexico reported that an intensive community-participatory educational campaign was associated with an improvement in knowledge and a reduction in PCC [29]; however, this study was not randomised and was conducted in only one community and ignored the dynamics of pig populations in rural areas, and the mode of delivering the training was not the same. Health education training has significantly improved awareness of *T. solium* infections, the transmission cycle of parasites, clinical signs of NCC and the knowledge of preventive measures related to human TSTC. Studies that have evaluated the effect of the health-education intervention on knowledge and preventive practices regarding human TSTC in the country are scarce. However, similar studies in Mbulu District, Tanzania [13,30] showed that an education intervention significantly improved knowledge of PCC; another similar study in Southern India and Mexico [29,36] also showed health education to significantly improve the knowledge of TSTC and the knowledge of the various ways in which NCC is transmitted. Therefore, efforts in providing an effective health-education intervention to the risky group regarding this infection will have a positive impact in improving knowledge and hence controlling the parasite.

However, the given health education training did not show significant improvement in preventive practices in intervention villages. The observed key preventive practices were those closely related to the transmission of human TSTC such as free-range pigs, the possession and use of toilets at each household, water sources for domestic use and hand cleanness after toilet use. This and other studies have shown that preventive practices against TSTC transmission are still suboptimal despite a high level of awareness and availability of preventive services. The finding of this study is consistent with the findings in other studies and demonstrated the effectiveness of health-education interventions in improving preventive practices against TSTC [13,29,37,38]. A lack of improved preventive practices might be attributed to a limited time to determine the effect, individual negligence, poverty, cultural beliefs and the observed inappropriate and insufficient public health services, such as the inadequate safe and clean water supply in most of the endemic areas of the country [10,35,39]. For example, it was observed that a shortage of safe and clean in most villages did not stop some people in the study areas from fetching water from unofficial water sources, a factor that might not be changed in the short run [35,40]. Despite the effort to control contamination by conducting training in the intervention group, contamination in the control group could occur. The health-education intervention resulted in a significant decrease in participants who always observed free-roaming pigs in both the intervention and control groups due to the effect of the intervention and the "Hawthorne effect." Furthermore, the observed practices were measured cross-sectionally and might not reflect the practices used most of the time. In consideration of the importance of preventive practices for infection prevention and control as a requirement, the need for information and positive attitude changes towards the disease is also important. Another important component of the present study was the estimation of the cumulative incidence of HCC a year post-intervention, which revealed that incidences of HCC were still detected in the study as measured by ag-ELISA and there was no significant difference in cumulative incidences between the control and intervention villages, meaning that the intervention did not reduce incidences of HCC as hypothesized. Besides this study, no other study has estimated the cumulative incidence of HCC under field conditions. The intervention trial conducted in Mbulu District, northern Tanzania attempted to examine the incidence rate of PCC in sentinel pigs. The intervention was associated with a considerable decrease in the incidence rate of PCC (incidence rate ratio 0.57) as measured by antigen-ELISA in sentinel pigs. However, the findings from this previous study cannot be compared with the findings of the present study, because the previous study had some difficulty in controlling the experimental conditions and had other important limitations, including a short follow-up period of pigs (4 months), and the small sample sizes in many villages studied, which resulted from participants withdrawing from the study [13].

The aim of training the trainers, and distributing leaflets and booklets to the audience was to ensure the sustainability of the training even after the one-time health education session. Nevertheless, this might have increased the likelihood of contamination of the intervention in the control villages.

5. Conclusions

This study has shown that the adapted health-education intervention strategy is effective in increasing knowledge and improving pig-confinement practices against human TSTC transmission in selected villages in the Kongwa and Songwe Districts. This is an important step forward in the control of *T. solium* infections. The observed cumulative incidence of HCC is an indication of persisting environmental contamination with *T. solium* eggs and improper sanitary and hygienic practices, and, therefore, a high risk of HCC. This study recommends further studies to determine the effect of time as a factor on health-education interventions for improving preventive practices against human TSTC transmission and reducing incidences of HCC and other public health challenges.

Author Contributions: G.M.: Contributed to conception and design of study, collection, analysis and interpretation of data; drafting and critical review of the manuscript. B.N.: Contributed to the designing of the study, analysis, interpretation of the data and the critical review of the manuscript. H.N.: Contributed to the conception and designing of the study, analysis and the critical review of the manuscript. C.W.: Contributed to the designing of the study and the data collection. E.M.: Contributed to the conception, the designing of the study and the critical review of the manuscript. A.S.W.: Contributed to the conception, the designing of the study and the critical review of the manuscript. J.N.: Contributed to the conception, the designing of study, collection, analysis and inter-

pretation of data and the critical review of the manuscript. All authors gave their final approval for manuscript submission. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the German Federal Ministry of Education and Research (BMBF) and facilitated by the CYSTINET-Africa consortium under CYTINET-Africa SUA project number 81203596 and CYSTINET-Africa TUM I project number 01KA1618. The funder had no role in the design of the study and collection, analysis, or interpretation of the data, or in the writing of the manuscript.

Institutional Review Board Statement: This research was approved by the ethical committee of the Sokoine University of Agriculture (Ref. No. PVM//D/2018/0074) and the study protocol was revised and approved by the Tanzania National Institute for Medical Research (NIMR)(NIMR/HQ/R.8a/Vol.1X/2802). The study also received approval from the ethics committee of the Klinikum rechts der Isar, Technical University of Munich, Germany, under the number of 537/18 S-KK. Permission to carry out the study was also provided by the district, ward and village government authorities of Kongwa and Songwe District Council.

Informed Consent Statement: Consent for the participation of the selected participants in a household was obtained from the selected individuals as well as the head of the household. Before sampling, each selected participant was approached individually to obtain written informed consent. For minors (<18 years), informed assents were obtained orally from them and thereafter written informed consent forms were signed by their parents or guardians.

Data Availability Statement: The datasets generated and analysed for this study are not publicly available due to participants' privacy, but are available from the corresponding author upon reasonable request.

Acknowledgments: The authors would like to thank the German Federal Ministry of Education and Research in collaboration with the Sokoine University of Agriculture (SUA) (Tanzania) and the Technical University of Munich (TUM), Germany, for facilitating this inter/transdisciplinary research on poverty-related and neglected diseases. Special thanks should also be extended to participating households from the Kongwa and Songwe Districts who willingly offered their valuable time to participate in this study, as well as all stakeholders and partners including District Veterinary, Medical Officers and village local leaders for their support.

Conflicts of Interest: The authors declare no competing interest. All authors have approved the final article submission.

References

1. WHO. *Preventable Epilepsy: Taenia solium Infection Burdens Economies, Societies and Individuals*; WHO: Geneva, Switzerland, 2016. Available online: https://apps.who.int/iris/handle/10665/204716 (accessed on 6 September 2018).
2. Craig, P.; Pawłowski, Z. *Cestode Zoonoses: Echinococcosis and Cysticercosis: An Emergent and Global Problem*; IOS Press: Amsterdam, The Netherlands, 2002.
3. Sarti-Gutierrez, E.J.; Schantz, P.M.; Lara-Aguilera, R.; Gomez Dandoy, H.; Flisser, A. *Taenia solium* Taeniasis and Cysticercosis in a Mexican Village. *Trop. Med. Parasitol.* **1988**, *39*, 194–198. [PubMed]
4. Braae, U.; Saarnak, C.; Mukaratirwa, S.; Devleesschauwer, B.; Magnussen, P.; Johansen, M. *Taenia solium* Taeniosis/Cysticercosis and the Co-Distribution with Schistosomiasis in Africa. *Parasites Vectors* **2015**, *8*, 323. [CrossRef] [PubMed]
5. Braae, U.C.; Magnussen, P.; Harrison, W.; Ndawi, B.; Lekule, F.; Johansen, M.V. Effect of National Schistosomiasis Control Programme on *Taenia solium* Taeniosis and Porcine Cysticercosis in Rural Communities of Tanzania. *Parasite Epidemiol. Control* **2016**, *1*, 245–251. [CrossRef] [PubMed]
6. Carabin, H.; Krecek, R.C.; Cowan, L.D.; Michael, L.; Foyaca-Sibat, H.; Nash, T.; Willingham, A.L. Estimation of the Cost of *Taenia solium* Cysticercosis in Eastern Cape Province, South Africa. *Trop. Med. Int. Health* **2006**, *11*, 906–916. [CrossRef] [PubMed]
7. Mwanjali, G.; Kihamia, C.; Kakoko, D.V.C.; Lekule, F.; Ngowi, H.; Johansen, M.V.; Thamsborg, S.M.; Willingham, A.L. Prevalence and Risk Factors Associated with Human *Taenia solium* Infections in Mbozi District, Mbeya Region, Tanzania. *PLoS Negl. Trop. Dis.* **2013**, *7*, e2102. [CrossRef] [PubMed]
8. Mwang'onde, B.; Nkwengulila, G.; Chacha, M. The Serological Survey for Human Cysticercosis Prevalence in Mbulu District, Tanzania. *Adv. Infect. Dis.* **2012**, *2*, 62–66. [CrossRef]
9. Kalage, R.E. Lay People's Knowledge, Perceptions and Practices Regarding the Transmission and Management of Human and Porcine Cysticercosis in Mbeya Rural District of Tanzania. Master's Thesis, University of Nairobi, Nairobi, Kenya, 2009. Available online: http://erepository.uonbi.ac.ke/handle/11295/5338 (accessed on 1 June 2022).

10. Mwang'onde, B.J.; Nkwengulila, G.; Chacha, M. The Risk Factors for Human Cysticercosis in Mbulu District, Tanzania. *Onderstepoort J. Vet. Res.* **2014**, *81*, a719. [CrossRef]
11. Trevisan, C.; Devleesschauwer, B.; Schmidt, V.; Winkler, A.S.; Harrison, W.; Johansen, M.V. The Societal Cost of *Taenia solium* Cysticercosis in Tanzania. *Acta Trop.* **2017**, *165*, 141–154. [CrossRef]
12. Sarti, E.; Rajshekhar, V. Measures for the Prevention and Control of *Taenia solium* Taeniosis and Cysticercosis. *Acta Trop.* **2003**, *87*, 137–143. [CrossRef]
13. Ngowi, H.A.; Carabin, H.; Kassuku, A.A.; Mlozi, M.R.S.; Mlangwa, J.E.D.; Willingham, A.L. A Health-Education Intervention Trial to Reduce Porcine Cysticercosis in Mbulu District, Tanzania. *Prev. Vet. Med.* **2008**, *85*, 52–67. [CrossRef]
14. Carter, C.N.; Ronald, N.C.; Steele, J.H.; Young, E.; Taylor, J.P.; Russell, L.H.; Eugster, A.K.; West, J.E. Knowledge-Based Patient Screening for Rare and Emerging Infectious/Parasitic Diseases: A Case Study of Brucellosis and Murine Typhus. *Emerg. Infect. Dis.* **1997**, *3*, 73–76. [CrossRef] [PubMed]
15. Nyangi, C.; Stelzle, D.; Mkupasi, E.M.; Ngowi, H.A.; Churi, A.J.; Schmidt, V.; Mahonge, C.; Winkler, A.S. Knowledge, Attitudes and Practices Related to *Taenia solium* Cysticercosis and Taeniasis in Tanzania. *BMC Infect. Dis.* **2022**, *22*, 534. [CrossRef]
16. Eom, K.S.; Chai, J.-Y.; Yong, T.-S.; Min, D.-Y.; Rim, H.-J.; Kihamia, C.; Jeon, H.-K. Morphologic and Genetic Identification of *Taenia* Tapeworms in Tanzania and DNA Genotyping of *Taenia Solium*. *Korean J. Parasitol.* **2011**, *49*, 399. [CrossRef] [PubMed]
17. Komba, E.V.G. Prevalence of Porcine Cysticercosis in Mbozi and Mbeya Rural Districts, Mbeya Tanzania. Master's Thesis, Sokoine University of Agriculture, Morogoro, Tanzania, 2008.
18. Maganira, J.D.; Hepelwa, N.I.; Mwang'onde, B.J. Seroprevalence of Porcine Cysticercosis in Ludewa District, Njombe, Tanzania. *Adv. Infect. Dis.* **2018**, *8*, 151. [CrossRef]
19. National Bureau of Statistics—Agriculture Statistics. Available online: https://www.nbs.go.tz/index.php/en/census-surveys/agriculture-statistics (accessed on 28 July 2021).
20. National Bureau of Statistics—2012 PHC: Regional Profiles. Available online: https://www.nbs.go.tz/index.php/en/regional-profiles (accessed on 1 November 2020).
21. Martin, S.W.; Meek, A.H.; Willeberg, P. *Veterinary Epidemiology: Principles and Methods*; Iowa State University Press: Ames, IA, USA, 1987.
22. Projects | KoboToolbox. Available online: https://kobo.humanitarianresponse.info/#/forms (accessed on 22 July 2020).
23. Penrith, M.-L. Cysticercosis Working Group in Eastern and Southern Africa—6th General Assembly. *J. S. Afr. Vet. Assoc.* **2009**, *80*, 206–207. [PubMed]
24. Deckers, N.; Dorny, P. Immunodiagnosis of *Taenia solium* taeniosis/cysticercosis. *Trends Parasitol.* **2010**, *26*, 137–144. [CrossRef]
25. Dorny, P.; Brandt, J.; Geerts, S. Immunodiagnostic approaches for detecting *Taenia solium*. *Trends Parasitol.* **2004**, *20*, 259–260. [CrossRef]
26. Dorny, P.; Brandt, J.; Zoli, A.; Geerts, S. Immunodiagnostic tools for human and porcine cysticercosis. *Acta Trop.* **2003**, *87*, 79–86. [CrossRef]
27. Saegerman, C.; Benitez-Ortiz, W.; Ahounou, S.; Barrionuevo-Samaniego, M.; Speybroeck, N.; Rodriguez-Hidalgo, R.; Dorny, P.; Hul, A.V.; Berkvens, D.; Praet, N. Infection with versus Exposure to *Taenia solium*: What Do Serological Test Results Tell Us? *Am. J. Trop. Med. Hyg.* **2010**, *83*, 413–415. [CrossRef]
28. Erhart, A.; Dorny, P.; Van De, N.; Vien, H.V.; Thach, D.C.; Toan, N.D.; Cong, L.D.; Geerts, S.; Speybroeck, N.; Berkvens, D.; et al. *Taenia solium* cysticercosis in a village in northern Viet Nam: Seroprevalence study using an ELISA for detecting circulating antigen. *Trans. R. Soc. Trop. Med. Hyg.* **2002**, *96*, 270–272. [CrossRef]
29. Sarti, E.; Flisser, A.; Schantz, P.M.; Gleizer, M.; Loya, M.; Plancarte, A.; Avila, G.; Allan, J.; Craig, P.; Bronfman, M.; et al. Development and Evaluation of a Health Education Intervention against *Taenia solium* in a Rural Community in Mexico. *Am. J. Trop. Med. Hyg.* **1997**, *56*, 127–132. [CrossRef] [PubMed]
30. Mwidunda, S.A.; Carabin, H.; Matuja, W.B.M.; Winkler, A.S.; Ngowi, H.A. A School Based Cluster Randomised Health Education Intervention Trial for Improving Knowledge and Attitudes Related to *Taenia solium* Cysticercosis and Taeniasis in Mbulu District, Northern Tanzania. *PLoS ONE* **2015**, *10*, e0118541. [CrossRef] [PubMed]
31. Carabin, H.; Gyorkos, T.W.; Soto, J.C.; Joseph, L.; Payment, P.; Collet, J.-P. Effectiveness of a Training Program in Reducing Infections in Toddlers Attending Day Care Centers. *Epidemiology* **1999**, *10*, 219–227. [CrossRef] [PubMed]
32. Ngowi, H.; Ozbolt, I.; Millogo, A.; Dermauw, V.; Somé, T.; Spicer, P.; Jervis, L.L.; Ganaba, R.; Gabriel, S.; Dorny, P.; et al. Development of a Health Education Intervention Strategy Using an Implementation Research Method to Control Taeniasis and Cysticercosis in Burkina Faso. *Infect. Dis. Poverty* **2017**, *6*, 95. [CrossRef]
33. Maridadi, A.F.; Lwelamira, J.; Simime, F.G. Knowledge and Practices Related to *T. solium* Cysticercosis-Taeniasis among Smallholder Farmers in Selected Villages in Kilolo District in Iringa Region in Southern Highlands of Tanzania. *Int. J. Anim. Vet. Adv.* **2011**, *3*, 196–201.
34. Maganira, J.D.; Mwang'onde, B.J.; Kidima, W.; Mwita, C.J.; Höglund, J. Seroprevalence of Circulating Taeniid Antigens in Pigs and Associated Risk Factors in Kongwa District, Tanzania. *Parasite Epidemiol. Control* **2019**, *7*, e00123. [CrossRef]
35. Thomas, D.J.; Holbro, D.N.; Young, M.D. *A Review of Sanitation and Hygiene in Tanzania*; DFID: London, UK, 2013; 86p.
36. Sankhyan, P.; Gupta, S.; Singh, G. Knowledge about, Attitudes towards, Practices Regarding *Taenia solium* Cysticercosis among People Attending an Epilepsy Clinic in India. *Int. J. Epilepsy* **2015**, *2*, 6–10. [CrossRef]

37. Levy, M.; Wohlgemut, J.; Mutua, F.; Dewey, C. Evaluating the Efficacy of Teaching Methods Regarding Prevention of Human Epilepsy Caused by *Taenia solium* Neurocysticercosis in Western Kenya. *Am. J. Trop. Med. Hyg.* **2010**, *82*, 634–642. [CrossRef]
38. Alexander, A.M.; Mohan, V.R.; Muliyil, J.; Dorny, P.; Rajshekhar, V. Changes in Knowledge and Practices Related to Taeniasis/Cysticercosis after Health Education in a South Indian Community. *Int. Health* **2012**, *4*, 164–169. [CrossRef]
39. World Health Organization. *WHO Estimates of the Global Burden of Foodborne Diseases*; World Health Organization, Ed.; World Health Organization: Geneva, Switzerland, 2015.
40. Tanzania-Sanitation Review. Available online: https://assets.publishing.service.gov.uk/media/57a08a2fed915d3cfd000628/tanzania-sanitationreview.pdf (accessed on 7 January 2022).

CHAPTER FIVE

5.0 GENERAL DISCUSSION, CONCLUSIONS AND RECOMMENDATIONS

5.1 General Discussion

The study utilized a community based health education intervention as a strategy to increase knowledge, improve preventive practices against human TSTC and ultimately reduce incidences of HCC among community members in the selected intervention villages of Kongwa and Songwe Districts. The comparison of the pre–post-randomisation change in knowledge, preventive practice and cumulative incidence of HCC between the control and intervention groups was a specifically meant to determine the effect of the intervention itself in one group. This study also provides valuable data to be used for designing future intervention strategies through which an effective and sustainable strategy may be identified and used to reduce *T. solium* transmission.

This community based health education intervention has been undertaken with an emphasis on increasing knowledge about human TSTC transmission and management, expected to influence change in practices with an ultimate decrease in the incidence rate of the infection in the study areas. An increase in knowledge and improvement in preventive practices of people living in areas where *T. solium* is endemic can prevent transmission of the parasite, either through reducing the likelihood that a person could become infected with a tapeworm, reducing the potential for personal contamination with *T. solium* eggs, reducing the potential for environmental contamination and by reducing the opportunity for human to become infected. The study was carried in the area where PCC is endemic and the most important pig producing in the country. The infections had previously been reported in the study areas and a number of control options had been piloted (Komba *et al.,* 2013; Mwanjali *et al.,* 2013; Kabululu *et al.,* 2018; Maganira *et al.,* 2019). However, studies that evaluated the effect of health education intervention on knowledge, attitude, practice and prevalence of human *T. solium* infections are scarce. The study is therefore limited in comparing the effect sizes of this intervention with other similar studies.

The baseline study found the community knowledge regarding human TSTC, transmission, control and prevention was low in both intervention and control villages. Findings also indicated only 17.5% of participants had heard about human TSTC, although it is not surprising as no one had ever heard anything about HCC. Furthermore, the majority (88.5%) of respondents could not agree that the infections might lead to epileptic condition in human especially when transmission involves the CNS. Not only the knowledge on the impact of *T. solium* on human health in general population was limited, also the majority (86.2%) of participants did not consider themselves at risk of the infections, despite living in TSTC endemic areas*.* This study and other studies (Maridadi, Lwelamira and Simime, 2011; Mwang'onde, Nkwengulila and Chacha, 2014; Nyangi *et al.,* 2022) have consistently shown that community knowledge regarding human *T. solium* infections was low and recommended a specific and targeted community health education among the risk group. The community health education intervention conducted in intervention villages resulted in increase in knowledge, whereby significantly higher ($p < 0.001$) knowledge mean scores was observed in the intervention group compared to the control group revealing that there was an improvement in knowledge among respondents that received the intervention. The study observed a significant increase ($p < 0.001$) of respondents who were aware of human TSTC in intervention group compared to the control group. Likewise, knowledge of transmission dynamics and the various aspects of prevention and control in human had significantly increased ($p < 0.001$) in intervention villages. This important finding means that, the adapted health-education intervention strategy is effective in increasing knowledge against human TSTC transmission in selected villages in the Kongwa and Songwe Districts. This is an important step forward in the control of *T. solium* infections. This study is in agreement with reports from other few studies where health education intervention was evaluated showing significant improvement in knowledge regarding TSTC (Sarti *et al.,* 1997; Ngowi *et al.,* 2008; Ngowi *et al.,* 2011; Alexander *et al.,* 2012; Mwidunda *et al.,* 2015; Ertel *et al.,* 2017; Carabin *et al.,* 2018; Hobbs *et al.,* 2018).

Another important component of the community health education intervention was to improve preventive practices related to human TSTC in the study area. During the baseline study, most of the preventive practices related to human TSTC, transmission, hygiene and sanitation were low in both intervention and control villages. The majority of participants had agreed to always observe scavenging pigs in the study villages. The study also observed almost half of participants had no toilet/latrines at their household, revealing open field defecation practices, as they also agreed to always observe human feces in farms and around their premises. The study also observed majority of participants from control and intervention group were using water from unofficial sources which was not clean and safe sources for their domestic purposes, contributing to transmission of various infectious diseases including TSTC. These findings revealed a significant knowledge gap and adverse practices regarding human TSTC transmission and management, leading to misconceptions and ineffective control measures in the study area. Moreover, having primary education or higher is not sufficient to have knowledge and better practices on prevention of transmission of TSTC. Other studies (Ngowi *et al.* 2004b, 2008; Maridadi, Lwelamira and Simime, 2011; Mkupasi, Ngowi and Nonga, 2011; Mwanjali *et al.,* 2013; Nyangi *et al.,* 2022) also reported consistent findings of low level practices related to TSTC in other endemic areas of the country and recommended a specific health education intervention among at risk groups.

Preventive practices related to human TSTC were also assessed one year after the community based education intervention. However, in this study like previous studies, despite an intensive education intervention, no statistical improvement was evident in sanitary and hygienic practices related to transmission of human TSTC among participants from control and intervention groups when assessed after the education intervention. Free-ranging system of pig production, domestic use of water from unofficial source and absence/low quality toilets at the household were still found to be risky practices in this study despite the education intervention as also noted in similar studies. A lack of improved preventive practices might be attributed by limited time to determine the effect, individual negligence, poverty, cultural beliefs and the observed inappropriate and insufficient public health services such as the inadequate safe and clean water supply in most of the endemic areas of the country. Most of the study villages were observed to have no reliable source of safe and clean water, causing some community members to depend on unofficial water sources which were neither safe nor clean, a factor that might not be changed in the short run. Similar observation in endemic areas have also found free-range pig production was associated with feed seasonality and failure of farmers to keep pigs indoors during the dry season because of poverty, a factor that might not be changed in the short-run (Ngowi *et al.,* 2007b).

The study hypothesized that, improved knowledge and preventive practices in the community as a result of community health educational intervention, could reduce incidences of HCC in the study areas within a year. Before the educational intervention, total 12 human cases of HCC were detected using Ag-ELISA, among the detected cases, each village group (control and intervention) had 6 cases of HCC. The detected cases at baseline (1.4% by Ag-ELISA) were significantly associated with age and presence of IgG-antibodies (p <0.001), where participants who were 45 years of age and above were strongly associated with HCC likewise for participants detected with IgG-antibodies. The baseline prevalence of this study was low compared to the prevalence of previous study conducted in Mbozi and Mbulu close to the study area (Mwang'onde, Nkwengulila and Chacha 2012; Mwanjali *et al.,* 2013). The difference might be associated with difference in study design, diagnostic methods used and increase of interventions in some endemic areas. A year post health-education intervention, estimation of cumulative incidence of HCC were 6 cases per 324 and 4 cases per 338 participants from the control and intervention groups respectively, whereby no significant difference in incidence rates were found between the two groups. These incidences recorded during the post health-education intervention excluded the cases detected during the baseline study. Because the sensitivity and specificity of the Ag-ELISA are 86.7% and 94.7%, respectively (Dorny *et al.,* 2004), the observed incidence of HCC is probably close to the true incidence. There is no evidence of other studies which had estimated the cumulative incidence of

HCC under field conditions, however, one study in Mbulu District examined the incidence rate of PCC in sentinel pigs, which was 69 cases per 100 pigs in the control group (Ngowi *et al.,* 2008). Because of the small sample size included in the analysis (n = 100), and the fact that the authors tried to measure new infections in pigs, those findings cannot be compared with the findings of the present study. Therefore, the observed cumulative incidence of HCC in these studies is an indication of persisting environmental contamination with *T. solium* eggs, which is a major risk of HCC.

5.2 Conclusions

Persistence of HCC in Kongwa and Songwe Districts which are among the leading pig producing areas in Tanzania indicates environmental contamination with *T. solium* eggs from human carriers. Nevertheless, poor knowledge of the community regarding the infections was probably responsible for observed risky practices responsible for infections perpetuation. This study has shown that community based health education is an effective intervention in increasing knowledge for controlling human TSTC with a long term impact. However, this intervention requires multidisciplinary input and active participation of the community. It also needs infrastructure improvements such as the construction of standard latrines/toilets, pigpens and reliable source of clean and safe water to facilitate change in the people's practices.

5.3 Recommendations

To address this public health problem of global concern, the following recommendations can be made;

(i) Developing effective control measures: There is a need for the development of effective control measures that target both the human and animal hosts of TSTC. This can include mass drug administration, vaccination, and animal husbandry practices that reduce the risk of infection.

(ii) Implementation of community health education: There should be a concerted effort to educate the community about the transmission, symptoms, and treatment of TSTC. Health education campaigns should be designed to reach a broad audience, including school children, community leaders, and the general population.

(iii) Improve sanitation and hygiene: Improving sanitation and hygiene practices can prevent the spread of TSTC. Health officials should promote proper disposal of human faeces, encourage handwashing with soap and discourage drinking of untreated water.

(iv) Strengthen surveillance systems: Surveillance systems should be strengthened to improve early detection and treatment of TSTC cases. This can be done through the establishment of TSTC surveillance programme at the community level, with trained community health workers actively searching for cases.

(v) Developing effective control measures: There is a need for the development of effective control measures that target both the human and animal hosts of TSTC. This can include mass drug administration, vaccination, and animal husbandry practices that reduce the risk of infection.

References

Afonso, S., Vaz, Y., Neves, L., Pondja, 1., Dias1, A., Willingham, M., Vilhena, P. Duarte, C. and Noor Mahomed. E. (2011). Human and porcine *Taenia solium* infections in Mozambique: identifying research priorities. *Animal Health Research Reviews*; 12:123–129.

Alexander, A. M., Mohan, V. R., Muliyil, J., Dorny, P. and Rajshekhar, V. (2012). Changes in knowledge and practices related to taeniasis/cysticercosis after health education in a south Indian community. *International Health* 4(3): 164–169.

Allan, J.C., Craig, P.S. and Noval, J.G. (1992). Coproantigen detection for immunodiagnostic of echinococcosis and taeniasis in dogs and humans. *Parasitology*; 104:347–355.

Allan, J. C., Avila, G., García Noval, J., Flisser, A. and Craig, P. S. (2003). Immunodiagnostic tools for taeniasis. *Acta Tropica*; 87:87–93.

Arriola, C. S., Gonzalez, A. E., Gomez-Puerta, L. A., Lopez-Urbina, M. T., García, H. H. and Gilman, R. H. (2014). New insights in cysticercosis transmission. *PLOS Neglected Tropical Diseases* 8(10): e3247.

Assana, E., Kyngdon, C. T., Gauci, C. G., Geerts, S., Dorny, P., De Deken, R., Anderson, G. A., Zoli, A. P. and Lightowlers, M. W. (2010). Elimination of *Taenia solium* transmission to pigs in a field trial of the TSOL18 vaccine in Cameroon. *International Journal for Parasitology*; 40:515–519.

Balami, A.D., Said, S. M., Zulkefli, N. A., Zulkefli, M., Bachok, M. and Bala Audu, B. (2019). Effects of a health educational intervention on malaria knowledge, motivation, and behavioural skills: a randomized controlled trial. *Malaria Journa*; 18:41-45.

Bati, J., Legesse, M. and Medhin, G. (2013). Community's knowledge, attitudes and practices about tuberculosis in Itang Special District, Gambella Region, South Western Ethiopia. *BMC Public Health*; 13:734.

Bisallah, C. I., Rampal, L. L. and ye, M.S. (2018). Effectiveness of health education intervention in improving knowledge, attitude, and practices regarding Tuberculosis among HIV patients in General Hospital Minna, Nigeria – A randomized control trial. García-Basteiro A (ed.). *PLoS ONE*;13: e0192276.

Boa, M. E., Kassuku, A. A., Willingham, A. L., Keyyu, J. D., Phiri, I. K. and Nansen, P. (2003). Regional action plan for combating *Taenia solium* cysticercosis/taeniosis in Eastern and Southern Africa. *Acta Tropica;* 87:183–186.

Braae, U. C., Magnussen, P., Harrison, W., Ndawi, B., Lekule, F. and Johansen, M. V. (2016b). (2015). *Taenia solium* taeniosis/cysticercosis and the co-distribution with schistosomiasis in Africa. *Parasites & Vectors*; 8: 323.

Braae, U. C., Magnussen, P., Ndawi, B., Harrison, W., Lekule, F. and Johansen, M. V. (2017a). Effect of National Schistosomiasis Control Programme on *Taenia solium* taeniosis and porcine cysticercosis in rural communities of Tanzania. *Parasite Epidemiology and Control*; 1:245–251.

Brooks, J. T., Ochieng, J. B., Kumar, L., Okoth, G., Shapiro, R. L., Wells, J. G., Bird, M., Bopp, C., Chege, W., Beatty, M. E., Chiller, T., Vulule, J. M., Mintz, E. and Slutsker, L. (2006). Surveillance for Bacterial Diarrhea and Antimicrobial Resistance in Rural Western Kenya, 1997-2003. *Clinical Infectious Diseases*; 43:393–401.

Camara, N., Ngasala, B., Leyna, G., Abade1, A., Rumisha. S., Oriyo, N. and Mboera, L. (2018). Socio-demographic determinants of dengue infection during an outbreak in Dar es Salaam City, Tanzania. *Tanzania Journal of Health Research*; 20, DOI: 10.4314/thrb. v 20i2.3.

Cao, W., van der Ploeg, C. P., Xu, J., Gao, C., Ge, L. and Habbema, J. D. (1997). Risk factors for human cysticercosis morbidity: a population-based case-control study. *Epidemiology & Infection*; 119:231–235.

Cao, W.C., van der Ploeg, C.P. and Gao, C.L. (2006). Seroprevalence and risk factors of human cysticercosis in a community of Shandong, China. *Southeast Asian Pacific Journal of Tropical Medicine Health*; 27:279–285.

Carabin, H., Krecek, R. C., Cowan, L. D., Michael, L., Foyaca-Sibat, H., Nash, T. and Willingham, A. L. (2006). Estimation of the cost of *Taenia solium* cysticercosis in Eastern Cape Province, South Africa. *Tropical medicine & international health* 11:906–916.

Carabin, H., Krecek, R. C., Cowan, L. D., Michael, L., Foyaca-Sibat, H., Nash, T. and Willingham, A. L. (2009). Seroprevalence to the Antigens of *Taenia solium* Cysticercosis among Residents of Three Villages in Burkina Faso: A Cross-Sectional Study. Flisser A (ed.). *PLoS Neglected Tropical Diseases*; 3: e555.

Carabin, H., Ndimubanzi, P. C., Budke, C. M., Nguyen, H., Qian, Y., Cowan, L. D., Stoner, J. A., Rainwater, E. and Dickey, M. (2011). (2011). Clinical Manifestations Associated with Neurocysticercosis: A Systematic Review. Flisser A (ed.). *PLOS Neglected Tropical Diseases*; 5: e1152.

Carabin, H., Millogo, A., Cissé, A., Gabriël, S., Sahlu, I., Dorny, P., Bauer, C., Tarnagda, Z., Cowan, L. D. and Ganaba, R. (2015). Prevalence of and Factors Associated with Human Cysticercosis in 60 Villages in Three Provinces of Burkina Faso. Zhang W (ed.). *PLOS Neglected Tropical Diseases;* 9: e0004248.

Carpio, A., Escobar, A. and Hauser, W.A. (1998) Cysticercosis and Epilepsy: A Critical Review. *Epilepsia*; 39:1025–1040.

Carter, C.N., Ronald, N.C. and Steele, Cruz, M., Davis, A., Dixon, H., Pawlowski, Z. S. and Proano, J. (2007). Knowledge-based patient screening for rare and emerging infectious/parasitic diseases: a case study of brucellosis and murine typhus. *Emerging Infectious Diseases;* 3:73–76.

Coral-Almeida, M., M., Gabriël, S., Abatih, E. N., Praet, N., Benitez, W. and Dorny, P. (2015). (2015). *Taenia solium* Human Cysticercosis: A Systematic Review of Sero-epidemiological Data from Endemic Zones around the World. Torgerson PR (ed.). *PLOS Neglected Tropical Diseases*;9: e0003919.

Coral-Almeida, M., Rodríguez-Hidalgo, R., Celi-Erazo, M., García, H. H., Rodríguez, S., Devleesschauwer, B., Benítez-Ortiz, W., Dorny, P. and Praet, N. (2014). Incidence of human Taenia solium larval infections in an Ecuadorian endemic area: implications for disease burden assessment and control. *PLOS Neglected Tropical Diseases* 8(5): e2887.`

Craig, P. and Pawłowski, Z. (2002). *Cestode Zoonoses: Echinococcosis and Cysticercosis: An Emergent and Global Problem*. IOS Press. 55-61pp.

Daniel, W.W. and Cross, C.L. (1998). Biostatistics: A Foundation for Analysis in the Health Sciences. :958.

Deckers. N. and Dorny, P. (2010). Immunodiagnostics of *Taenia solium* taeniosis/cysticercosis. *Trends in parasitology;* 26:137–144.

Dohoo, I.R., Martin, S.W. and Stryhn, H. (2009). *Veterinary Epidemiologic Research*. Charlottetown, P.E.: VER, Inc. 45–55pp.

Dorny, P., Brandt, J., Zoli, A. and Geerts, S. (2004). Immunodiagnostic approaches for detecting *Taenia solium*. *Trends in Parasitology*; 20:259–260.

Dorny, P., Vercammen, F., Brandt, J., Vansteenkiste, W., Berkvens, D. and Geerts, S. (2003). Immunodiagnostic tools for human and porcine cysticercosis. *Acta Tropica*; 87:79–86.

Edia-Asuke, A.U., Inabo, H.I. and Mukaratirwa, S., Mukaratirwa, S., Umoh1, V., Whong1, C., Asuke. S. and Ella1, E. (2015). Seroprevalence of human cysticercosis and its associated risk factors among humans in areas of Kaduna metropolis, Nigeria. *Journal of Infection*9: 799–805.

Elisante, R. (2009). Lay people's knowledge, perceptions and practices regarding the transmission and management of human and porcine cysticercosis in Mbeya, Tanzania.[http://erepository.uonbi.ac.ke:8080/handle/123456789/5338]. Accessed on 6/1/2022.

Engels, D., Urbani, C. and Belotto, A. (2003). The control of human (neuro)cysticercosis: which way forward? *Acta Tropica*;87: 177–82.

Eom, K. S., Chai. J.Y. and Yong T-S. (2011). Morphologic and Genetic Identification of *Taenia* Tapeworms in Tanzania and DNA Genotyping of *Taenia solium*. *The Korean Journal of Parasitology*; 49:399.

Eom, K.S, Jeon, H. and Kong, Y. (2002). Identification of *Taenia asiatica* in China: Molecular, morphological, and epidemiological analysis of a Luzhai isolate. *Journal of Parasitology*; 88:758–764.

Fabiani. S. and Bruschi, F. (2013). Neurocysticercosis in Europe: Still a public health concern not only for imported cases. *Acta Tropica*; 128: 18–26.

Ferrer, E., Cortez, M., Cabrera, Z., Rojas, B., Dávila, I., Alarcón, B., Pérez, H., Fernandez, I., Urdaneta, R., Leslie, S., Harrison, R., Michael, E. and Gárate, T. (2005). Oncospheral peptide-based ELISAs as potential sero-epidemiological tools for *Taenia solium* cysticercosis / neurocysticercosis in Venezuela. *Transactions of the Royal Society of Tropical Medicine and Hygiene*; 99:568–76.

Flisser, A., Sarti, E., Lightowlers, M. and Schantz, P. (2006). Where are the tapeworms? *Parasitology International*; 55: S117–120.

Flisser, A. (2013). State of the Art of *Taenia solium* as Compared to *Taenia asiatica*. *The Korean Journal of Parasitology*; 51:43–49.

Flisser, A., Gauci, C.G. and Zoli, A. (2004). Induction of Protection against Porcine Cysticercosis by Vaccination with Recombinant Oncosphere Antigens. *Infection and Immunity;* 72:5292–5297.

Flisser, A., Rodríguez-Canul, R. and Willingham, A.L. (2006). Control of the taeniosis/cysticercosis complex: Future developments. *Veterinary Parasitology*; 139:283–292.

Flisser, A., Gauci, C. G., Zoli, A., Martinez-Ocaña, J., Garza-Rodriguez, A., Dominguez-Alpizar, J. L., Maravilla, P., Rodriguez-Canul, R., Avila, G., Aguilar-Vega, L., Kyngdon, C., Geerts, S. and Lightowlers, M. W. (2003). Neurocysticercosis: regional status, epidemiology, impact and control measures in the Americas. *Acta Tropica*; 87:43–51.

Freeman, M.C., Ogden, Flisser, A., Gauci, C. G., Zoli, A., Martinez-Ocaña, J., Garza-Rodriguez, A., Dominguez-Alpizar, J. L., Maravilla, P., Rodriguez-Canul, R., Avila, G., Aguilar-Vega, L., Kyngdon, C., Geerts, S. and Lightowlers, M. W. (2013). Integration of Water, Sanitation, and Hygiene for the Prevention and Control of Neglected Tropical Diseases: A Rationale for Inter-Sectoral Collaboration. Liang S (ed.). *PLOS Neglected Tropical Diseases*; e2439.

Gabriël, S., Dorny, P., Mwape, K. E., Trevisan, C., Braae, U. C., Magnussen, P., Thys, S., Bulaya, C., Phiri, I. K., Sikasunge, C. S., Makungu, C., Afonso, S., Nicolau, Q. and Johansen, M. V. (2017). Control of *Taenia solium* taeniasis/cysticercosis: The best way forward for sub-Saharan Africa? *Acta Tropica*; 165:252–260.

Garcia, H.H. and Del Brutto, O.H. (2000) *Taenia solium* cysticercosis. *Infectious Disease Clinics of North America;* 14:97–119, ix.

García, H.H., Evans, C.A. A. E., Rodriguez, S., Tsang, V. C. W., Pretell, E. J., Gonzales, I., Gilman, R. H. and Cysticercosis Working Group in Peru. (2002). Current Consensus Guidelines for Treatment of Neurocysticercosis. *Clinical Microbiology Reviews*; 15:747–756.

García, H.H., González, A.E. Tsang, V. C. W., O'Neal, S. E., Llanos-Zavalaga, F., Gonzalvez, G., Romero, J., Rodriguez, S., Moyano, L. M., Ayvar, V., Diaz, A., Hightower, A., Craig, P. S., Lightowlers, M. W., Gauci, C. G., Leontsini, E., Gilman, R. H. and Cysticercosis Working Group in Peru. (2007). Strategies for the elimination of taeniasis/cysticercosis. *Journal of the Neurological Sciences*;262: 153–157.

García, H.H., Gonzalez, A.E. and Evans, C.W. (2003). *Taenia solium* cysticercosis. *Lancet*; 362:547–556.

Garcia, H.H., Gonzalez, A. E. and Gilman, R.H. (2001). Short report: transient antibody response in *Taenia solium* infection in field conditions-a major contributor to high seroprevalence. *American Journal of Tropical Medicine and Hygiene;* 65:31–32.

Garcia, H.H, Nash, T.E. and Del Brutto, O.H. (2014) Clinical symptoms, diagnosis, and treatment of neurocysticercosis. *The Lancet Neurology*;13: 1202–1215.

Garcia, H.H., Pretell, E.J. Parkhouse, R. M. E., Gilman, R. H., Montenegro, T., Bernal, T., Martinez, S. M., Gonzalez, A. E., Tsang, V. C. W. and Harrison, L. J. S. and Gilman, R.H. (2004). A Trial of Antiparasitic Treatment to Reduce the Rate of Seizures Due to Cerebral Cysticercosis. *New England Journal of Medicine;* 350: 249–258.

Garcia, H. H., Nash, T. E. and Del Brutto, O. H. (2014). *Clinical symptoms, diagnosis, and treatment of neurocysticercosis. The Lancet Neurology, 13(12), 1202–1215.*

Gonzales, I., Rivera, J.T., Garcia, H.H., García, H. H., Gilman, R. H., Tsang, V. C. W. and Cysticercosis Working Group in Peru. (2016). Pathogenesis of *Taenia solium* taeniasis and cysticercosis. *Parasite Immunol*;38: 136–146.

Gonzalez, A.E., García, H. H., Gilman, R. H., Tsang, V. C. W. and Cysticercosis Working Group in Peru. (2003). Control of *Taenia solium*. *Acta Tropica*; 87:103–109.

Gonzalez, A.E., Gauci, C.G. and Barber, D. (2005). Vaccination of pigs to control human neurocysticercosis. *American Journal of Tropical Medicine and Hygiene;* 72: 837–839.

González, L.M., Villalobos, N., Montero, E., Morales, J., Sanz, R. A., Muro, A., Harrison, L. J. S., Parkhouse, R. M. E. and Gárate, T. (2000). Differential Diagnosis of *Taenia saginata* and *Taenia solium* Infection by PCR. *Journal of Clinical Microbiology;* 38:737–744.

González, L.M., Montero, E. and Puente, S. (2002). PCR tools for the differential diagnosis of *Taenia saginata* and *Taenia solium* taeniasis/cysticercosis from different geographical locations. *Diagn Microbiology and Infection;* 42: 243–249.

Mayta,H. , Talley, A. Jimenez, A., Verastegui, M., Ruiz, H., Garcia, B. and Gilman, R.H.(2000). Differentiating *Taenia solium* and *Taenia saginata* infections by simple hematoxylin-eosin staining and PCR-restriction enzyme analysis. *Journal of clinical microbiology*;38, DOI: 10.1128/JCM.38.1.133-137.2000.

Hotez, P.J., Bottazzi, M.E. and Franco-Paredes, C. (2008). The Neglected Tropical Diseases of Latin America and the Caribbean: A Review of Disease Burden and Distribution and a Roadmap for Control and Elimination. Lammie PJ (ed.). *PLOS Neglected Tropical Diseases;* 2: e300.

Huerta, M., Aluja, A.S., Fragoso, G. Toledo, A., Villalobos, N., Hernández, M., Gevorkian, G., Acero, G., Díaz, A., Alvarez, I., Avila, R., Beltrán, C., García, G., Martinez, J. J., Larralde, C. and Sciutto, E. (2001). Synthetic peptide vaccine against *Taenia solium* pig cysticercosis: successful vaccination in a controlled field trial in rural Mexico. *Vaccine* 2001; 20:262–266.

http://www.nbs.go.tz/nbs/takwimu/Agriculture/DODOMA%20REGION %20REPORT. Accessed on 9/3/2020.

Ito, A., Yamasaki, H., Nakao, M., Sako, Y., Okamoto, M., Sato, M. O., Nakaya, K., Margono, S. S., Ikejima, T., Kassuku, A. A., Afonso, S. M. S., Ortiz, W. B., Plancarte, A., Zoli, A., Geerts, S. and Craig, P. S. (2003). Immunodiagnostic and molecular approaches for the detection of taeniid cestode infections. *Trends in Parasitology;* 19:377–381.

Johansen, M. V., Trevisan, C., Gabriël, S., Magnussen, P. and Braae, U. C. (2017). Are we ready for *Taenia solium* cysticercosis elimination in sub-Saharan Africa? *Parasitology*; 144:59–64.

Kabululu, M. L., Ngowi, H. A., Kimera, S. I., Lekule, F. P., Kimbi, E. C. and Johansen, M. V. (2015). Risk factors for prevalence of pig parasitoses in Mbeya Region, Tanzania. *Veterinary Parasitology*; 212: 460–464.

Kabululu, M.L., Ngowi, H.A., Mlangwa J.E.D and Johansen, M. V. (2020). TSOL18 vaccine and oxfendazole for control of *Taenia solium* cysticercosis in pigs: A field trial in endemic areas of Tanzania. *PLOS Neglected Tropical Diseases;*14: e0008785.

Kang, I.S., Kim, D.H. and, Hee. G. (2012). Impact of health education on the prevalence of enterobiasis in Korean preschool students. *Acta Tropica* 2012; 122:59–63.

Kanobana, K., Praet, N. and Kabwe, C. (2011). High prevalence of *Taenia solium* cysticerosis in a village community of Bas-Congo, Democratic Republic of Congo. *International Journal for Parasitology*;41: 1015–1018.

https://www.WHO.int/publications/i/item/9241546204]. Site visited on 25/4/2021.

Kelvin, E. A., Carpio, A., Bagiella, E., Leslie, D., Leon, P., Andrews, H. and Hauser, W. A. (2011). Seizure in people with newly diagnosed active or transitional neurocysticercosis. *Seizure*; 20:119–125.

Kisinza, W., Talbert, A. Mutalemwa, P. and MCCALL, P. (2008). Community knowledge, attitudes and practices related to tick-borne relapsing fever in Dodoma Rural District, Central Tanzania. *Tanzania Journal of Health Research;* 10:131–136.

Komba, E.V.G. (2008). Prevalence of porcine cysticercosis in Mbozi and Mbeya rural districts, Mbeya Tanzania. Master's Thesis, Sokoine University of Agriculture, Morogoro, Tanzania.

Komba, E.V.G., Kimbi, E.C. and Ngowi, H.A. (2013). Prevalence of porcine cysticercosis and associated risk factors in smallholder pig production systems in Mbeya region, southern highlands of Tanzania. *Veterinary Parasitology*; 198:284–291.

Kungu, J.M., Dione, M.M. and Ejobi, F. (2017). Risk factors, perceptions and practices associated with *Taenia solium* cysticercosis and its control in the smallholder pig production systems in Uganda: a cross-sectional survey. *BMC Infectious Diseases*; 17:1-7.

Levy, M., Wohlgemut, J., Dewey, C. and Mutua, F. (2010a). Evaluating the Efficacy of Teaching Methods Regarding Prevention of Human Epilepsy Caused by *Taenia solium* Neurocysticercosis in Western Kenya. *The American Journal of Tropical Medicine and Hygiene*; 82:634–642.

Levy, M., Wohlgemut, J. and Mutua, F. (2010b). Evaluating the Efficacy of Teaching Methods Regarding Prevention of Human Epilepsy Caused by *Taenia solium* Neurocysticercosis in Western Kenya. *The American Journal of Tropical Medicine and Hygiene*; 82:634–642.

Lightowlers, M.W. (2010). Eradication of *Taenia solium* cysticercosis: a role for vaccination of pigs. *International Journal for Parasitology;* 40: 1183–1192.

Mafojane, N. A., Appleton, C. C., Krecek, R. C., Michael, L. M. and Willingham, A. L. (2003). The current status of neurocysticercosis in Eastern and Southern Africa. *Acta Tropica;* 87:25–33.

Maganira, J. D., Hepelwa, N. I. and Mwang'onde, B. J. (2018). Seroprevalence of Porcine Cysticercosis in Ludewa District, Njombe, Tanzania. *Advances in Infectious Diseases*; 08:151-155.

Maganira, J. D., Mwang'onde, B. J.and Kidima. W. (2019). Seroprevalence of circulating taeniid antigens in pigs and associated risk factors in Kongwa district, Tanzania. *Parasite Epidemiology and Control*;7: e00123.

Maridadi, A. F., Lwelamira, J. and Simime, F.G. (2011). Knowledge and Practices Related to *T. solium* Cysticercosis - Taeniasis among Smallholder Farmers in Selected Villages in Kilolo District in Iringa Region in Southern Highlands of Tanzania. *International Journal of Animal and Veterinary Advances 3(3):* 196-201.

Martin, S.W., Meek, A.H. and Willeberg, P. (1987). *Veterinary Epidemiology: Principles and Methods*. Iowa State University Press, Ames IA.

Meštrović, T., Sviben, M. and Vilibić-Čavlek, T. (2012). Seroprevalence of *Taenia solium* infections in Croatian patients presenting with epilepsy. *Journal of Helminthology*; 86:259–262.

Millogo, A., Ngowi, A.H. and Carabin, H. (2019). Knowledge, attitudes, and practices related to epilepsy in rural Burkina Faso. *Epilepsy & Behavior*; 95:70–74.

Mkonda, M. and He, X. (2017). Are Rainfall and Temperature Really Changing? Farmer's Perceptions, Meteorological Data, and Policy Implications in the Tanzanian Semi-Arid Zone. *Sustainability*;9: 1412.

Mkupasi, E. M., Ngowi, H. A., Sikasunge, C. S., Leifsson, P. S. and Johansen, M. V. (2013a). (2011). Prevalence of extra-intestinal porcine helminth infections and assessment of sanitary conditions of pig slaughter slabs in Dar es Salaam city, Tanzania. *Tropical Animal Health and Production;* 43: 417–423.

Morales, J., Martínez, J. J., Manoutcharian, K., Hernández, M., Fleury, A., Gevorkian, G., Acero, G., Blancas, A., Toledo, A., Cervantes, J., Maza, V., Quet, F., Bonnabau, H., de Aluja, A. S., Fragoso, G., Larralde, C. and Sciutto, E. (2008). Inexpensive anti-cysticercosis vaccine: S3Pvac expressed in heat inactivated M13 filamentous phage proves effective against naturally acquired Taenia solium porcine cysticercosis. *Vaccine*; 26:2899–2905.

Murrell, K., Darwin, D. P., Flisser, A., Geerts, S., Kyvsgaard, N. C., McManus, D. P., Nash, T. E. and Pawlowski, Z. (Eds.) (2005). *FAO/WHO/OIE Guidelines for the* 113 *Surveillance, Prevention and Control of Taeniosis/cysticercosis*. World Organization for Animal Health (WOAH), World Health Organization (WHO) and the Food and Agriculture Organization of the United Nations (FAO), Paris. 139pp.

Mutua, F., Arimi, S. and Ogara, W. (2010). Farmer Perceptions on Indigenous Pig Farming in Kakamega District, Western Kenya. *Nordic African Studies;*19: 43–57.

Mwang'onde BJ, Nkwengulila G, Chacha M. (2014). The risk factors for human cysticercosis in Mbulu District, Tanzania. *Onderstepoort Journal of Veterinary Research;* 81, DOI: 10.4102/ojvr. v 81i2.719.

Mwang'onde, B., Nkwengulila, G. and Chacha, M. (2012). The Serological Survey for Human Cysticercosis Prevalence in Mbulu District, Tanzania. *Advances in Infectious Diseases*;02: 62–66.

Mwanjali, G., Kihamia, C., Kakoko, D. V. C., Lekule, F., Ngowi, H., Johansen, M. V., Thamsborg, S. M. and Willingham, A. L. (2013). Prevalence and risk factors associated with human *Taenia solium* infections in Mbozi District, Mbeya Region, Tanzania. *PLoS Neglected Tropical Diseases 7*(3): e2102.

Mwape, K. E., Phiri, I. K., Praet, N., Muma, J. B., Zulu, G., Bossche, P. V. den, Deken, R. de, Speybroeck, N., Dorny, P. and Gabriël, S. (2012). *Taenia solium* Infections in a Rural Area of Eastern Zambia-A Community Based Study. Jex AR (ed.). *PLOS Neglected Tropical Diseases;* 6: e1594.

Mwidunda, S. A., Carabin, H., Matuja, W. B. M., Winkler, A. S. and Ngowi, H. A. (2015). A school based cluster randomised health education intervention trial for improving knowledge and attitudes related to *Taenia solium* cysticercosis and taeniasis in Mbulu district, northern Tanzania. *PLoS ONE*;10: e0118541.

National Bureau of Statistics (2012): Regional Profiles. Available online: [https://www.nbs.go.tz/index.php/en/regionalprofiles]. [Accessed on 1/11/ 2020].

National Bureau of Statistics and Agriculture.Available online: [https://www.nbs.go.tz/index.php/en/census-surveys/agriculture-statistics]. [Accessed on 28/7/ 2021).

Ndimubanzi, P. C., Carabin, H., Budke, C. M., Nguyen, H., Qian, Y.-J., Rainwater, E., Dickey, M., Reynolds, S. and Stoner, J. A. A. (2010). Systematic Review of the Frequency of Neurocyticercosis with a Focus on People with Epilepsy. Preux P-M (ed.). *PLoS Neglected Tropical Diseases*;4: e870.

Ngowi, H., Phiri, I. and Afonso, S.(2004a). *Taenia solium* cysticercosis in Eastern and Southern Africa: An emerging problem in agriculture and public health. *Southeast Asian Southeast Asian Journal of Tropical Medicine and Public Health*; 35:5-10.

Ngowi, H. A., Kassuku, A. A., Maeda, G. E. M., Boa, M. E. and Willingham, A. L. (2004b). Risk factors for the prevalence of porcine cysticercosis in Mbulu District, Tanzania. *Veterinary Parasitology*; 120:275–283.

Ngowi, H. A., Mlangwa, J. E. D., Carabin, H., Mlozi, M. R. S., Kassuku, A. A., Kimera, S. I. and Willingham, A. L. (2007). Using the PRECEDE model to plan a health promotion strategy for control of *Taenia solium* infections in northern Tanzania. *International Journal of Health Promotion and Education*; 45:41–48.

Ngowi, H.A., Carabin, H., Kassuku, A. A., Mlozi, M. R. S., Mlangwa, J. E. D. and Willingham, A. L. (2008). A health-education intervention trial to reduce porcine cysticercosis in Mbulu District, Tanzania. *Preventive Veterinary Medicine*; 85:52–67.

Ngowi, H.A., Mlangwa, J.E., Mlozi, M.R. Mbilinyi, B. P. and Willingham, A. L. (2009). Implementation and evaluation of a health-promotion strategy for control of *Taenia solium* infections in northern Tanzania. *International Journal of Health Promotion and Education*; 47: 24–34.

Ngowi, H. A., Kassuku, A. A., Carabin, H., Mlangwa, J. E. D., Mlozi, M. R. S., Mbilinyi, B. P. and Willingham, A. L. (2010). Spatial clustering of porcine cysticercosis in Mbulu district, northern Tanzania. *PLoS PLOS Neglected Tropical Diseases;* 4: e652.

Ngowi, H., Ozbolt, I., Millogo, A., Dermauw. V., Somé, T., Spicer, P., Lori, L., Rasmané, G., Gabriel, S., Dorny, P., and Carabin, H. (2017). Development of a health education intervention strategy using an implementation research method to control taeniasis and cysticercosis in Burkina Faso. *Infectious Diseases of Poverty;* 6:95-97.

Ngowi, H. A., Winkler, A. S., Braae, U. C., Mdegela, R. H., Mkupasi, E. M., Kabululu, M. L., Lekule, F. P. and Johansen, M. V. (2019). *Taenia solium* taeniosis and cysticercosis literature in Tanzania provides research evidence justification for control: A systematic scoping review. Devleesschauwer B (ed.). *PLoS ONE*; 14: e0217420.

Nkwengulila, G. (2014). The Financial Costs Associated with Porcine Cysticercosis and Epilepsy in Iringa Rural District. *Tanzania Journal of Health Research;* 06:2959.

Nyangi, C., Stelzle, D., Mkupasi1, E., Ngowi1, H., Churi, A., Schmidt, V., Mahonge, C. and Winkler, A. S. (2022). Knowledge, attitudes and practices related to *Taenia solium* cysticercosis and taeniasis in Tanzania. *BMC Infectious Diseases;* 22:534.

Pandian, J., Girotra, M. and Gera, C. (2011). Awareness of neurocysticercosis: A study from Northwest India. *Annals of Indian Academy of Neurology*; 14:27.

Pawlowski, Z., Allan, J. and Sarti, E. (2005). Control of *Taenia solium* taeniasis/cysticercosis: From research towards implementation. *International Journal for Parasitology*; 35:1221–1232.

Phiri, I. K., Ngowi, H., Afonso, S., Matenga, E., Boa, M., Mukaratirwa, S., Githigia, S., Saimo, M., Sikasunge, C., Maingi, N., Lubega, G. W., Kassuku, A., Michael, L., Siziya, S., Krecek, R. C., Noormahomed, E., Vilhena, M., Dorny, P. and Lee Willingham III, A. (2003). The emergence of *Taenia solium* cysticercosis in Eastern and Southern Africa as a serious agricultural problem and public health risk. *Acta Tropica*; 87:13–23.

Poudel, I., Sah, K., Subedi, S., Singh, D. K., Kushwaha, P., Colston, A., Gauci, C. G., Donadeu, M. and Lightowlers, M. W. (2019). Implementation of a practical and effective pilot intervention against transmission of *Taenia solium* by pigs in the Banke district of Nepal. Fuehrer H-P (ed.). *PLOS Neglected Tropical Diseases;* 13: e0006838.

Praet, N., Speybroeck, N., Rodriguez–Hidalgo, R., Benitez-Ortiz, W., Berkvens, D., Brandt, J., Saegerman, C. and Dorny, P. (2010a). *Taenia solium* Cysticercosis in the Democratic Republic of Congo: How Does Pork Trade Affect the Transmission of the Parasite? Garcia HH (ed.). *PLOS Neglected Tropical Diseases;* 4: e817.

Praet, N., Rodriguez-Hidalgo, R., Speybroeck, N., Ahounou, S., Benitez-Ortiz, W., Berkvens, D., Hul, A. V., Barrionuevo-Samaniego, M., Saegerman, C. and Dorny, P. (2010b). Age-related infection and transmission patterns of human cysticercosis. *International Journal for Parasitology*; 40:85–90.

Prasad, K. N., Prasad, A., Gupta, R. K., Pandey, C. M. and Singh, U. (2007). Prevalence and associated risk factors of *Taenia solium* taeniasis in a rural pig farming community of north India. *Transactions of the Royal Society of Tropical Medicine and Hygiene*;101: 1241–1247.

Preux, P. M. and Druet-Cabanac, M. (2005). Epidemiology and aetiology of epilepsy in sub-Saharan Africa. *The Lancet Neurology*; 4:21–31.

Quet, F., Guerchet, M., Pion, S. D. S., Ngoungou, E. B., Nicoletti, A. and Preux, P.-M. (2010). Meta-analysis of the association between cysticercosis and epilepsy in Africa. *Epilepsia*; 51:830–837.

Raccurt, C.P., Agnamey, P. and Boncy, J. (2009). Seroprevalence of human *Taenia solium* cysticercosis in Haiti. *Journal of Helminthology;* 83:113–116.

Rodriguez–Hidalgo, R., Benitez-Ortiz, W., Praet, N., Saa, L. R., Vercruysse, J., Brandt, J. and Dorny, P. (2006). Taeniasis-cysticercosis in Southern Ecuador: Assessment of infection status using multiple laboratory diagnostic tools. *Memorias Do Instituto Oswaldo Cruz* 101(7): 779–782.

Rodriguez, S., Wilkins, P. and Dorny, P. (2012). Immunological and molecular diagnosis of cysticercosis. *Pathogens and Global Health*; 106:286–298.

Rodríguez-Hidalgo, R., Benítez-Ortiz, W., Dorny, P., Geerts, S., Geysen, D., Ron-Román, J., Proaño-Pérez, F., Chávez-Larrea, M. A., Barrionuevo-Samaniego, M., Celi-Erazo, M., Vizcaíno-Ordóñez, L. and Brandt, J. (2002). Comparison of conventional techniques to differentiate between *Taenia solium* and *Taenia saginata* and an improved polymerase chain reaction-restriction fragment length polymorphism assay using a mitochondrial 12S rDNA fragment. *Journal of Parasitology;* 88: 1007–1011.

Rodríguez-Hidalgo, R., Benítez-Ortiz, W. and Dorny, P. (2003). Taeniosis–cysticercosis in man and animals in the Sierra of Northern Ecuador. *Veterinary Parasitology*; 118:51–60.

Sankhyan, P., Gupta, S. and Singh, G. (2015). Knowledge about, attitudes towards, practices regarding Taenia solium cysticercosis among people attending an epilepsy clinic in India. *International Journal of Epilepsy*; 02:6–10.

Sarti, E., Flisser, A., Schantz, P. M., Gleizer, M., Loya, M., Plancarte, A., Avila, G., Allan, J., Craig, P., Bronfman, M. and Wijeyaratne, P. (1997). Development and evaluation of a health education intervention against Taenia solium in a rural community in Mexico. *American Journal of Tropical Medicine and Hygiene;* 56: 127–132.

Sarti, E., Schantz, P. M., Avila, G., Ambrosio, J., Medina–Santillán, R. and Flisser, A (2003). Measures for the prevention and control of *Taenia solium* taeniosis and cysticercosis. *Acta Tropica;* 87:137–143.

Schantz, P. M., Wilkins, P. P. and Tsang, V. C. W. (2003). The US Centers for Disease Control and Prevention (CDC) and research and control of cysticercosis. *Acta Tropica*; 87:161–163.

Sciutto, E., Fragoso, G., Fleury, A., Laclette, J. P., Sotelo, J., Aluja, A., Vargas, L. and Larralde, C. (2007). The immune response in *Taenia solium* cysticercosis: protection and injury. *Parasite immunology;* 29:621–636.

Sikasunge, C. S., Johansen, M. V., Willingham, A. L., Leifsson, P. S. and Phiri, I. K. (2008). Prevalence of *Taenia solium* porcine cysticercosis in the Eastern, Southern and Western provinces of Zambia. *Veterinary Journal;* 176:240–244.

Singh, G. and Prabhakar, S. (2002). *Taenia Solium* Cysticercosis: *From Basic to Clinical Science*. *Wallingford: CAB*I; 31:174-180.

Sohrabi. M., Amin. R., Maher. A., Amin1. R., Maher, A and Ali, R. (2021). Sociodemographic determinants and clinical risk factors associated with COVID-19 severity: a cross-sectional analysis of over 200,000 patients in Tehran, Iran. *BMC Infectious Diseases*; 21:474-480.

Taeniasis/Cysticercosis.[https://www.who.int/news-room/fact-sheets/detail/taeniasis-cysticercosis] Accessed on 5/12/2021.

Thomas, D.J., Holbro, D.N. and Young, M.D. (2013). A Review of Sanitation and Hygiene in Tanzania; *DFID: London, UK;* 86p.

Thomas, L. F. (2014). Epidemiology of *Taenia solium* cysticercosis in western Kenya. Unpublished Thesis for Award of the Degree of Doctor of Philosophy at University of Edinburgh, Edinburgh, Scotland. 220pp. [https://era.ed.ac.uk/handle/1842/8849] Accessed on 22/8/2018].

Thys, S., Mwape, K. E., Lefèvre, P., Dorny, P., Marcotty, T., Phiri, A. M., Phiri, I. K. and Gabriël, S. (2016). Why pigs are free-roaming: Communities' perceptions, knowledge and practices regarding pig management and taeniosis/cysticercosis in a *Taenia solium* endemic rural area in Eastern Zambia. *Veterinary Parasitology*; 225:33–42.

Torgerson, P.R., Rüegg, S. and Devleesschauwer, B. (2018). zDALY: An adjusted indicator to estimate the burden of zoonotic diseases. *One Health*; 5:40–55.

Trevisan, C., Devleesschauwer, B., Schmidt, V., Winkler, A. S., Harrison, W. and Johansen, M. V. (2017). Are we ready for *Taenia solium* cysticercosis elimination in sub-Saharan Africa? *Parasitology*; 144:59–64.

Tsang, V. C., Brand, J. A. and Boyer, A. E. (1989). An enzyme-linked immunoelectrotransfer blot assay and glycoprotein antigens for diagnosing human *Taenia solium* cysticercosis. *International Journal of Infectious Disease;* 159:5059-5062.

Vega, R., Piñero, D. and Ramanankandrasana, B. (2003). Population genetic structure of *Taenia solium* from Madagascar and Mexico: implications for clinical profile diversity and immunological technology. *International Journal for Parasitology;* 33:1479–1485.

Vilhena, M., Santos, M. and Torgal, J. (1999). Seroprevalence of human cysticercosis in Maputo, Mozambique. *American Journal of Tropical Medicine and Hygiene*; 61:59–62.

Vora SH, Motghare DD, Ferreira and Frediric, S. (2008). High Prevalence of Human Cysticercosis in a Rural Village in Western India. *Tropical Medicine and Health*; 36:137–138.

Wang, M. and Fang, H. (2020). The effect of health education on knowledge and behavior toward respiratory infectious diseases among students in Gansu, China: a quasi-natural experiment. *BMC Public Health*; 20:681-685.

White, A.C. (2000). Neurocysticercosis: Updates on Epidemiology, Pathogenesis, Diagnosis, and Management. *Annual Review of Medicine*; 51:187–206.

WHO. (2012). *Guidelines on management of Taenia solium neurocysticercosis*. World Health Organization (WHO), Geneva. 49pp. [https://www.who.int/publications-detail-redirect/9789240032231]

WHO/FAO. (2014). *Multicriteria-based ranking for risk management of food-borne parasites, Microbiological Risk Assessment Series 23, Expert Meeting on Food–Borne Parasites.* World Health Organization (WHO)/ Food and Agriculture Organization of the United Nations (FAO), Rome. 302pp

WHO/FAO/OIE (2015). *Guidelines for the surveillance, prevention and control of taeniosis/cysticercosis.* World Health Organization (WHO), Geneva. 42pp. [http://www.who.int/taeniasis/resources/9290446560/en/]. Accessed on 23/8/2018.

WHO. (2016). *Preventable epilepsy: Taenia solium infection burdens economies, societies and individuals*. World Health Organization (WHO), Geneva. 191pp. [https://apps.who.int/iris/handle/10665/325293]. Accessed on 22/11/2022.

Wilkins, P. P., Allan, J. C., Verastegui, M., Acosta, M., Eason, A. G., García, H. H., Gonzalez, A. E., Gilman, R. H. and Tsang, V. C. (1999). Development of a serologic assay to detect *Taenia solium* taeniasis. *American Journal of Tropical Medicine and Hygiene*;60: 199–204.

Winkler, A.S. (2012). Neurocysticercosis in sub-Saharan Africa: a review of prevalence, clinical characteristics, diagnosis, and management. *Pathogens and Global Health*; 106:261–274.

Winkler, A.S., Blocher, J. and Auer, H. (2009). Epilepsy and neurocysticercosis in rural Tanzania—An imaging study. *Epilepsia*; 50:987–993.

Yamasaki, H., Allan, J.C. and Sato, M.O. (2004). DNA Differential Diagnosis of Taeniasis and Cysticercosis by Multiplex PCR. *Clinical Microbiology;* 42:548–553.

Younes, N., Behnke, J., Ismail, A., Ahmed, I., Marawan, A. and Abuh, M. (2021). Socio-demographic influences on the prevalence of intestinal parasitic infections among workers in Qatar. *Parasites & Vectors*; 14:63-68.

Zoli, A., Shey Njila, O., Assana, E., Nguekam, J.P., Dorny, P., Brandt, J. and Geerts, S. (2003). Regional status, epidemiology and impact of *Taenia solium* cysticercosis in Western and Central Africa. *Acta Tropica*; 87: 35–42.

APPENDICES

Appendix 1: Ethical Clearance Certificate for conducting medical research in Tanzania

THE UNITED REPUBLIC OF TANZANIA

National Institute for Medical Research
3 Barack Obama Drive
P.O. Box 9653
11101 Dar es Salaam
Tel: 255 22 2121400
Fax: 255 22 2121360
E-mail: ethics@nimr.or.tz

Ministry of Health, Community Development, Gender, Elderly & Children
University of Dodoma, Faculty of Arts and Social Sciences
Building No. 11
P.O. Box 743
40478 Dodoma

NIMR/HQ/R.8a/Vol. IX/2802

22nd June 2018

Helena Aminiel Ngowi
Sokoine University of Agriculture
College of Veterinary Medicine and Biomedical Sciences
P.O. Box 3021
Morogoro

RE: ETHICAL CLEARANCE CERTIFICATE FOR CONDUCTING MEDICAL RESEARCH IN TANZANIA

This is to certify that the research entitled: Development, evaluation and implementation of a practical education intervention package for prevention and control of *Taenia solium* cysticercosis and taeniosis in Tanz (Ngowi HA *et al.*) has been granted ethical clearance to be conducted in Tanzania.

The Principal Investigator of the study must ensure that the following conditions are fulfilled:

1. Progress report is submitted to the Ministry of Health, Community Development, Gender, Elderly & Children and the National Institute for Medical Research, Regional and District Medical Officers after every six months.
2. Permission to publish the results is obtained from National Institute for Medical Research.
3. Copies of final publications are made available to the Ministry of Health, Community Development, Gender, Elderly & Children and the National Institute for Medical Research.
4. Any researcher, who contravenes or fails to comply with these conditions, shall be guilty of an offence and shall be liable on conviction to a fine as per NIMR Act No. 23 of 1979, PART III Section 10(2).
5. Site: Mbulu, Babati, Mpwapwa, Kilolo, Rungwe, Mbinga, Nyasa, Kongwe and Songwe districts in Tanzania.

Approval is valid for one year: 22nd June 2018 to 21st June 2019.

Name: Prof. Yunus Daud Mgaya

Signature
CHAIRPERSON
MEDICAL RESEARCH COORDINATING COMMITTEE

Name: Prof. Muhammad Bakari Kambi

Signature
CHIEF MEDICAL OFFICER
MINISTRY OF HEALTH, COMMUNITY DEVELOPMENT, GENDER, ELDERLY & CHILDREN

CC: RMO of Manyara, Dodoma, Iringa, Mbeya and Ruvuma regions
DMOs/DEDs of Mbulu, Babati, Mpwapwa, Kilolo, Rungwe, Mbinga, Nyasa, Kongwe and Songwe districts

Appendix 2: Approval for PhD. Research Proposal

	SOKOINE UNIVERSITY OF AGRICULTURE *DIRECTORATE OF POSTGRADUATE STUDIES, RESEARCH, TECHNOLOGY TRANSFER AND CONSULTANCY* P.O. Box 3151, MOROGORO, Tanzania, *TEL: +255 23 264 0013, 023 264006-9, E-mail Address: drpgs@suanet.ac.tz*		
Our Ref:	PVM/D/2018/0074	**Our Date**	30th November, 2018

Mr. George I. Makingi,
Department of Veterinary Medicene and Public Health,
SUA - Morogoro.

Dear Mr. Makingi,

RE: APPROVAL OF YOUR PhD. RESEARCH APROPOSAL

Please refer to the above mentioned subject.

I am writing to inform you that the Chairman of SPGSC has noted the approval made by the Board of College of Veterinary Medicine and Biomedical Sciences for your PhD Research Proposal. This means you are now allowed to embark on your research work.

Wishing you all the best for studies.

Sincerely,

Director
Postgraduate studies, Research, Technology Transfer and Consultancy
Sokoine University of Agriculture
P. O. Box 3151, Morogoro
TANZANIA

Mr. D. L. Malack
For **DIRECTOR**

c.c. Principal, College of Veterinary Medicine and Biomedical Sciences
c.c. Chairman College Postgraduate Studies Committee
cc: Supervisors, Dr. B. Ngowi and Dr. J. Nzalawahe